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SPECIFICATION INVESTIGATION

AND DATA ASSESSMENT OF AN

ICE HAZARD DETECTION/COLLISION AVOIDANCE SYSTEM

Prepared for: **The Transportation Development Centre**
Transport Canada

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SPECIFICATION INVESTIGATION AND DATA ASSESSMENT OF AN ICE HAZARD DETECTION/COLLISION AVOIDANCE SYSTEM

By

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September 1983

PREPARED FOR THE

TRANSPORTATION DEVELOPMENT CENTRE

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17. Abstract

This project was initiated by the Transportation Development Centre to perform an evaluation of a set of field data collected by Remotec Applications Inc. during 1981. This data consisted primarily of recorded radar returns and supporting documentation for a collection of iceberg targets. The evaluation consisted of selecting the most promising targets which could be digitized and used for further analysis. The selected targets were subjected to some basic manipulations in order to assess the target data quality. The targets selected are considered to be useful for studies that attempt to evaluate radar signal processing techniques. A variety of techniques are proposed such as scan to scan integration.

Further development of the system specification for an integrated ice hazard detection/collision avoidance system was undertaken and reported. The area of emphasis centered upon the display requirements. Potential Canadian users and research organizations were consulted to identify development programs underway which could assist in system development.

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17. Résumé

Ce projet lancé par le CDT visait l'évaluation d'une base de données recueillie in situ par la firme Remotec Applications Inc. en 1981. Il s'agissait surtout d'enregistrements d'échos radar réfléchis par des icebergs et de la documentation correspondante. Les travaux de recherche ont consisté à sélectionner les cibles les plus appropriées dont les échos pourraient être traités, numérisés et utilisés aux fins d'exploitation ultérieure. Les cibles sélectionnées ont été au préalable traitées de manière à en vérifier la qualité du point de vue des émissions radar. Ces cibles serviraient éventuellement aux travaux de recherche visant à éprouver les techniques de traitement du signal dont un grand nombre sont proposées.

Après des travaux visant à affiner le descriptif d'un appareil intégré de détection des glaces flottantes, l'intérêt s'est porté sur le système de visualisation et ses exigences. Divers utilisateurs et organismes de recherche canadiens susceptibles de s'intéresser à ce programme ont été consultés au sujet des programmes de développement en cours dans ce domaine et pouvant profiter aux travaux du présent programme.

18. Mots-clés	19. Diffusion
Icebergs. Détection. Radar. Evaluation. Descriptif. Glaces flottantes. Dangers. Infrarouge. Traitement du signal.	Le CDT dispose d'un nombre limité d'exemplaires.

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SUMMARY REPORT FOR A SPECIFICATION INVESTIGATION AND DATA ASSESSMENT OF AN ICE HAZARD DETECTION/COLLISION AVOIDANCE SYSTEM

1 Summary Report

As offshore activity increases in the Arctic and off the East Coast, concerns for effective ice and iceberg detection and management have grown. The Transportation Development Centre initiated a program to attempt to provide a capability for a vastly improved ice detection and management system. This project, as part of that program, further develops a system specification based on a survey of operator needs and the capabilities of Canadian industry and academic institutions to meet those needs. The major area of effort during the project was expended on an evaluation of recorded radar data collected in 1981. The radar data consisted of a total of 371 iceberg targets with a questionable amount of ground truthing. The results of the evaluation are presented in the report along with recommendations for further data analysis.

2 Concerns and Requirements of Various Organizations

Most of the companies and organizations contacted stated that they were still interested in seeing the development of an improved surface-borne, multi sensor ice hazard detection/collision avoidance system (IHD/CAS). The system must be modular in its construction and should provide significantly improved detection ranges. For this reason, Petro Canada, Gulf Oil, Mobil Oil Canada, and Canterra Energy Ltd., are all involved in HF radar development programs. In addition, efforts are being undertaken to enhance X and S band radar performance. Shortfalls in present surface systems are accommodated by expensive airborne surveillance and ship patrols.

3 System Specification

The system specification describes the proposed Ice Hazard Detection/ Collision Avoidance System IHD/CAS. The system shall be used to collect and display ice and iceberg location data with inputs derived from the most up to date and capable sensors available or underdevelopment. Annex A depicts the system configuration.

4 Development Programs and Time Scales

An IHD/CAS should be developed by 1987. The following programs are considered capable of providing data or system options for inclusion in an IHD/CAS. Gulf Oil is conducting a program in the U.S.A. to adapt a CODAR for use on offshore platforms. Mobil Oil, Canterra and Petro Canada are currently sponsoring development of an HF multistatic radar at the Battelle Columbus Laboratories. This radar is advertised to have a 150 km range capability. Mobil Oil is also conducting a study to reveiw all methods of iceberg detection applicable to the Hibernia Oilfield. The Japan Radio Corporation, McGill University and McMaster University are all conducting signal enhancement programs with X, S and Ka band radars.

SOMMAIRE

1. INTRODUCTION

A mesure que s'intensifient le forage et les activités commerciales dans les eaux arctiques et au large du littoral Atlantique, l'intérêt pour un système de détection des glaces et de gestion des données recueillies s'accroît. C'est pourquoi le Centre de développement des transports a lancé un programme visant la réalisation d'un appareil qui irait plus loin que les systèmes existants. Dans le cadre de ce programme, il a proposé la présente étude qui affine le descriptif d'un système de détection et de gestion élaboré à partir des besoins ressentis et tenant compte des aptitudes des milieux industriels et scientifiques canadiens à y répondre. L'étude s'est concentrée sur une évaluation de la base de données rassemblée en 1981 et constituée surtout d'échos radar enregistrés. Elle comportait un total de 371 cibles radar dont la validation par des vérifications in situ reste douteuse. Le rapport rend compte du résultat des travaux d'évaluation ainsi que des recommandations du contractant concernant l'exploitation ultérieure de la base de données.

2. INTERET ET EXIGENCES

La plupart des compagnies et associations approchées ont réitéré leur intérêt pour un système perfectionné de détection des glaces flottantes à installer à bord des navires ou des ouvrages en mer et qui, de construction modulaire, comporterait plusieurs types de détecteurs et aurait une portée beaucoup plus longue. C'est pour cette raison que Petro Canada, Gulf Oil, Mobil Oil Canada et Canterra Energy Ltd s'intéressent toutes si vivement à la recherche dans le domaine du radar HF, qui complète celle qui se fait sur le radar en bandes X et S. Actuellement, les lacunes des systèmes de surveillance de surface sont comblées par des patrouilles aériennes et maritimes qui reviennent très cher.

3. DESCRIPTIF

Le descriptif élaboré concerne un système de détection des glaces flottantes capable de localiser celles-ci à partir des signaux émis par des détecteurs parmi les plus avancés et les plus efficaces qui soient. Ce système est schématisé à l'annexe A.

4. ETUDE EN COURS ET DATE DE REALISATION

La réalisation du système en question a pu être prévue pour 1987 grâce à l'apport des programmes d'étude suivants. Aux Etats-Unis, Gulf Oil cherche à adapter un CODAR aux plates-formes de forage. Mobil Oil, Canterra et Petro Canada financent les travaux de perfectionnement d'un radar HF multistatique qui se poursuivent aux laboratoires de Batelle Columbus et dont on dit qu'il peut avoir une portée de 150 km. Pour sa part, Mobil Oil conduit séparément un tour d'horizon des techniques de détection utilisables pour la protection des champs pétroliers Hibernia. Enfin, Radio Japon et les université McGill et McMaster ont lancé des programmes de recherche visant à renforcer le rapport signal/bruit du radar dans les bandes X, S et Ka.

5 Radar Data Assessment

These radar enhancement activities lead to the radar data collected by Remotec Applications Ltd. for TDC and Petro Canada. This data is unique in that it is the only available body of data available which concentrates on offshore iceberg targets.

An evaluation was conducted to attempt to find targets which would lend themselves to further signal processing. There were severe ground truthing problems encountered but the best targets were identified. Event AA-03, AB-10, AD-10, AH-09, BM-01 and CO-03 are identified as the 6 best targets. These targets would lend themselves to further signal processing to try and improve signal to noise ratios. Correlations were then attempted which would identify the best radar operating parameters. These were shown to include long pulse length and horizontal polarization. S band radar provided superior S/N ratios generally. No correlation could be made between sea state and signal to noise ratio.

Although only imprecise measurements could be made, it could be determined that S/N ratio increased with target size. As a result of these findings it could be determined that the data was of generally poor quality, with little ground truthing and poor measurement technique utilized. However, some useful targets were found for future signal processing.

6 Analysis Plan

An extensive analysis of iceberg targets selected during the study should be undertaken to trial various signal processing techniques and algorithms. This analysis will include digitization, scan conversion and the possible use of dynamic threshold processing.

7 Recommendations and Conclusions

Based on the radar data evaluation, further signal processing is recommended. However, the data set is poor overall, and valuable information on what is required in future field trials is perhaps the area were this data can be put to best use. In the discussions with research institutions during the conduct of this project, it was determined that there still exists a need for well documented iceberg data. A further field trial will be necessary to obtain this data.

System specification work should continue in order to be able to supply a system to users by 1987.

Finally, TDC should continue its efforts to coordinate, plan and fund activities which encourage and support the development of any ice detection systems.

5. EVALUATION DES DONNES RADAR

Toutes ces activités ont mené au projet lancé par le CDT et Petro Canada concernant la base de données radar, et réalisé par Remotec Applications Ltd. Cette base de données est unique en ce qu'elle est la seule à ne porter que sur des cibles marines, en l'occurrence des icebergs.

Ensuite, une évaluation a été faite visant à repérer les cibles pouvant se prêter à des travaux ultérieurs sur le traitement du signal. Ce qui fut fait malgré les sérieux problèmes posés par la vérification in situ. Les cibles jugées les meilleurs sont les suivantes: AA-03, AB-10, AD-10, AH-09,BM-01 et CO-03, du fait que les signaux obtenus se prêtent aisément à un traitement du signal dans le but de renforcer le rapport signal/bruit. Des essais ont été également faits pour trouver par corrélation les meilleurs paramètres de fonctionnement du radar. Il a été déterminé que parmi ceux-ci figurent une impulsion de longue durée et une polarisation horizontale, et que les meilleurs rapports signal/bruit ont été obtenus dans la bande S. Enfin, aucune corrélation n'a pu être établie entre états de mer et échos radar.

Malgré l'imprécision des mesures faites, il a pu être établi que le rapport signal/bruit s'améliore d'autant plus que la cible est grande. Il a été constaté suite aux résultats obtenus que la base de données était de piètre qualité, qu'elle était ambiguë et que l'on avait fait appel à des procédés de mesure discutables. N'empêche que des cibles ont pu être trouvées dont le signal pouvait se prêter à un traitement ultérieur.

6. ANALYSE ULTERIEURE

Une analyse approfondie des cibles sélectionnées par la présente étude devrait être faite dans le but d'éprouver les diverses techniques et les divers algorithmes utilisés pour le traitement du signal: numérisation, conversion de balayage et peut-être aussi le traitement à seuil dynamique.

7. RECOMMANDATIONS ET CONCLUSIONS

L'évaluation faite de la base des données radar indique qu'il y aurait lieu de pousser plus avant le traitement des signaux. Cependant, cette même base étant généralement de piètre qualité, nous pensons que sa plus grande utilité serait justement de montrer les lacunes à combler lors d'éventuels essais in situ. En effet, nos contacts avec les organismes de recherche nous ont montré qu'il existe toujours un besoin pour une base de données bien constituée sur les icebergs. Voilà donc l'objet de la recherche in situ qui devra être entreprise dans un proche avenir.

Les travaux portant sur l'affinement du descriptif devront se poursuivre de manière à permettre la réalisation d'un appareil d'ici 1987.

Enfin, le CDT doit continuer à coordonner, planifier et financer les projets visant à encourager et appuyer l'étude de systèmes de détection des glaces flottantes, quels qu'ils soient.

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1.0 Introduction

As offshore activity increases in the Beaufort Sea, Arctic Islands, and the East Coast, in particular the Labrador and Hibernia areas, the concerns for effective ice and iceberg detection and management have grown. These concerns have led to a great deal of effort being expended by the governments involved with offshore activity, both Federal and Provincial, the offshore operators and reasearch and development institutions to alleviate these problems. In many cases, programs and systems have been created to solve a particular ice detection or management problem for a particular user. An example is the Shipboard Ice Alert and Monitoring System produced by McElhanney Surveying and Engineering Ltd., for Dome Petroleum Ltd., in the Beaufort Sea. The various modelling programs that have been generated by Petro Canada to predict iceberg motion on the East Coast are another example. These examples and many others point to efforts being undertaken on a short term basis to make oil exploration and marine transportation activities safer and more economical in ice and iceberg infested waters.

Realizing the scope and amount of activity that has been undertaken, the Transportation Development Centre initiated a program to attempt to provide direction and encouragement to development activities concerned with this matter in order to provide, over a long term, a capability enabling offshore operators to obtain vastly improved ice and iceberg detection and management information. This capability would take the form of an integrated surface-borne ice hazard detection collision avoidance system (IHD/CAS) that would utilize the most up to date sensors available or planned and would also utilize the most up to date display available with enhanced capabilities. The system would hopefully be Canadian, at least for development purposes, and would reflect the needs of as many Canadian offshore operators as possible. This would of course necessitate it being somewhat modular in construction as needs vary considerably. The system would, however, provide a certain base level capability that would satisfy all present and future government regulations for this relatively new area of maritime operations. This would ensure safer and more efficient operation at sea, and provide a natural direction for Canadian research and development efforts.

To this end, the Transportation Development Centre initiated a study in the fall of 1982 to determine the overall needs of the operators involved in ice infested waters, as well as determine the products and services available to fill these needs in the research efforts underway. Once these requirements had been ascertained, a preliminary system specification was produced which, although general in nature, would fill as many of the requirements as possible and would be a system towards which research programs could be directed and instituted. A final report of these activties entitled "A Preliminary Specification for the Iceberg Detection Collision Avoidance System" is available from TDC.

As the next step in the development plan the Transportation Development Centre contracted Viatec Resource Systems Inc., of Calgary to continue with the specification investigation and also to evaluate and prepare a data assessment of field data that was collected by Remotec Applications Inc. for Petro Canada. This data, if useful, could be used in radar development programs currently underway and would be subsequently digitized and converted from its present format.

This report documents these activities and specifically is concerned with reporting on the following activities. First, the concerns and requirements of the offshore operators and those concerned with the offshore are discussed. This includes the various aspects of the preliminary system specification for the Ice Hazard Detection/Collision Avoidance System.

Following this, and keeping in mind the concerns and requirements, the system specification is developed further. It incorporates many changes over the preliminary system specification, especially with regard to the display system. However, it is still modular in its concept and capable of filling the majority of the needs of operators. The specifications also discusses some of the possible sensor options that could be included and some of their limitations.

When and how this proposed ice hazard detection system could be implemented is discussed in Chapter 4. Development time scales are discussed as well as development programs underway. The Canadian participants in the development effort are described in this chapter and they are considered to be capable of standing in the forefront of any future development programs.

The major findings of this study are concerned with the evaluation of the Remotec radar field tapes. The results will assist in determining the course of the Transporation Development Centre's future activities in the field of ice hazard detection system development.

In Chapter 6, a complete analysis plan is proposed based on the results of the data evaluation. This is then followed by final conclusions and recommendations.

2.0 Concerns and Requirements of Various Organizations

2.1 Introduction

Meetings were conducted by Viatec with the majority of the offshore operators of drilling rigs and agencies involved with regulating marine activity. The purpose of the meetings were to determine their feelings about the adequacy of present iceberg detection systems from an operational point of view and obtain new viewpoints on the direction that future efforts in the area of iceberg detection and management should take. A summary of each meeting follows. Generally speaking, the concerns expressed are similar to those expressed in 1982 when Viatec conducted its initial survey. Certainly the extent of the variety of requirements has not changed, and this supports our view that a multi-use system development must incorporate a certain amount of modularity in order to be cost-effective and practical.

2.2 Petro Canada

Petro Canada has been active in recent years on the Labrador shelf and as such has had to deal with the problems of icebergs and sea ice. According to Greg Warbanski and Dennis Nazerenko, Petro Canada feels the hazard posed by all sizes of icebergs is of concern, however, utilizing Dynamically Positioned rigs detection ranges to the radar horizon (ie., for an antenna height of 25 m the radar horizon is 20 km) would be adequate for this type of operation. Petro Canada also expressed concern for the detection of small icebergs in fog and also the deficiencies in the data base on icebergs.

Petro Canada has recently started drilling on the Grand Banks south of Hibernia with a Dynamically Positioned Semi-Submersible (SEDCO 710). This rig is presently anchored due to a thruster problem. More concern was expressed towards this mode (anchored) of operation as lead times must be greater than the radar horizon allows. Petro Canada is making up for this limited detection range of the rig-borne radar by utilizing aerial coverage provided by Atlantic Airways with a kingsway 200 equipped with photographic and video cameras. In situations requiring continuous coverage, a workboat may be strategically placed upstream from the rig.

Presently, Petro Canada is operating with standard radar equipment off Labrador, however, the SEDCO 710 is outfitted with Dual X and S Band systems mounted fore and aft, each radar being interswitchable through a Racal-Decca ARPA (Automatic Radar Plotting Aid) unit.

Petro Canada recognizes the limitations of the standard marine radar and as such is participating in a program for the development of a HF radar for applications in ice hazard detection. The development is presently being carried out by Batelle Institute of Columbus, Ohio.

General support was expressed for an integrated type system which would provide data from various sources, co-ordinated through a central distribution point, to those operators requiring this information for safe operation.

The overall impression obtained from Petro Canada was that the level of concern is not that great with the Dynamically Positioned operation and as such, any proposed system will be judged mainly on its cost/benefit performance.

2.3 Mobil Oil Canada Ltd.,

David North, Jim Ransom and Mike Hassel stated that Mobil Oil is presently operating three anchored semi-submersible rigs in the Grand Banks region. Perhaps of any offshore operator, Mobil has the best feel for the requirements for iceberg detection.

Mobil has equipped its' three rigs with state-of-the-art marine radar systems. These systems, manufactured by Racal-Decca, are comprised of an X and S Band radar with antennas colocated and synchronized. The radar signals may be displayed on a standard PPI display or an a Racal-Decca ARPA system. Mobil expressed a lot of hope for this system in providing tactical iceberg detection. However, concern was expressed towards the ability of any microwave radar to detect icebergs in adverse environmental conditions.

Presently, Mobil supplements shipborne detection by a fairly comprehensive overflight support program. When aircraft overflights are inconclusive about particular areas work boats are dispatched to the area to run search patterns. Mobil feels this type of operation ensures a certain level of security, however, weather conditions often limit the effective operation of the aircraft.

Discussion of the problem indicated that the operator feels the detection process is hampered by, in order of severity,

1) Iceberg shape, surface condition
2) Sea State
3) Precipitation

The immediate requirements of Mobil are in the area of more reliable (all weather) aircraft support and more efficient iceberg forecasting (48 hr.).

In the future Mobil would like to see a co-ordinated effort approach to provide total East Coast coverage.

2.4 Canterra Energy Ltd.,

Stan Johnston of Canterra stated that at present, Canterra is operating a Dynamically Positioned drillship off the Labrador Coast. The rig, Petrel, is equipped with standard marine radar equipment.

The major concerns of Canterra are for the problems of initially positioning of the vessel on location and effective ice management.

At the time of writing, Canterra has not had to leave the drilling site due to ice conditions. Presently Johnston feels that with the Dynamically Positioned rig, ice poses no great problem. Canterra presently does not rely on ice forecasts to make drilling decisions.

The emphasis for future work should be placed on long ranged tactical type detection systems such as the OTH (HF) radar program, new better towing techniques for icebergs and lastly better short range tactical detection, in that order.

2.5 The Newfoundland Petroleum Directorate

The opinion of Chris Noll and Dave Burley indicated that the major concern of the Petroleum Directorate is for the detection of bergy bits. Concern was also expressed for the identification of safety limits for each drilling situation providing reaction times for various operating and environmental condition and ice hazard. General concern was also expressed for effective vessel traffic management in areas of drilling operations.

The Petroleum Directorate prepared a study during 1983 entitled "Iceberg Detection Capability, A Two Part Study". The study was undertaken out of concerns for the capability of present ice hazard detection capability. The first part consists of an evaluation of selected marine radars for their iceberg detection capability. The second part provides a survey of ongoing research in the iceberg detection field. This study parallels, in some respects, the work being done by the Transportation Development Centre. The results of this work are likely to be used by Newfoundland when drafting new offshore drilling regulations.

The Petroleum Directorate already has fairly comprehensive regulations concerning ice hazard detection equipment, but these are subject to change.

2.6 Canadian Coast Guard

The Canadian Coast Guard is presently responsible for ship and ice management on the East Coast of Canada. Data from various sources ice observers, satellites, air reconnaissance [AES] are obtained by CCG through Ice Central in the form of ice and iceberg limits and positions.

The CCG presently co-operates with the oil companies by exchanging information about iceberg position. The major concern expressed by Greg Dernford of CCG Ice Operations was that of inadequate (timely) coverage of the area of responsibility. The present aerial and satellite coverage is often days behind and as a result such strategic information is often not reliable.

2.7 Canadian Oil and Gas Lands Administration

The St. John's office of COGLA is mainly concerned with monitoring offshore operations to ensure drilling regulations are followed. COGLA presently has no regulations concerning ice hazard detection equipment.

2.8 Conclusions

In short, a wide variety of detection ranges and resolutions are required, depending upon the situation. This supports the requirements stated in Appendix B. The only change which could be considered necessary would be to increase the desired detection ranges for a large and medium berg 20km to 100 to 150 km. This would permit 48 hour notice of potentially threatening icebergs. The bulk of the interest lies in long range HF radar detection, combined with high resolution short range systems and improved display and forecasting. More coordination by government is recommended.

The next two chapters will discuss the options available to accomplish this within the system specification and through the development programs underway.

3.0 System Specification

3.1 Introduction

This specification describes a proposed Ice Hazard Detection/Collision Avoidance System (IHD/CAS).[8] This system shall be used to collect and display ice and iceberg location data with inputs derived from a group of sensors.

The following documents of the exact issue shown, form a part of this Specification to the extent specified herein.

TP 4216 E	Feb. 83	Final Report	A Preliminary Specification for the Ice Hazard Dection/Collision Avoidance System.
MIL-STD-721	25 Aug. 66	Issue B	Definition of Effectiveness Terms for Reliability, Maintainability Human Factors and Safety
MIL-STD-810	10 Mar. 75	Issue C	Environment Test Methods
MIL-STD-210	15 Dec. 73	Issue B	Climatic Extremes for Military Equipment
MIL-STD-167	01 May 74	Type 1	Mechanical Vibrations of Shipboard Equipment
MIL-STD-108	04 Aug. 66	Issue E	Definitions of and Basic Requirements for Enclosures for Electric and Electronic Equipment
MIL-STD-1399	10 Dec. 72	Issue A	Interface Ltd. for Shipboard Systems, Electric Power
MIL-STD-454	01 Mar. 76	Issue E	Standard General Requirements for Electronic Equipment
MIL-E-16400	24 Dec. 74	Issue A	Electronic Equipment, Naval Ship and shore; General Specification for Interior Communication and Navigation Equipment.

The IHD/CAS shall consist of an integrated display system and associated sensors and processor capable of displaying a wide range of sensor video and synthetic information. It shall include the following classes of sensors:

Radars
Frame Sensors (LLLTV)
Line Scan Sensors (I/R)

The display shall consist of a high resolution colour T.V. type display. Colour has been selected as preferable over monochrome due to the results of experiments conducted by C-Core and Gulf Canada Resources. A grey scale shading experiment did not yield as promising results as other advanced colour display techniques. The results of the trial indicated that Grey level definition is not vital to ice tracking. In addition, a "Daylight" video display makes radar more accessible to users of ice information. Control electronics, operator interface and pixel memory shall be included. The display shall interface with a general purpose computer which can be programmed by users for individual applications. These applications shall include ice management procedures and collision avoidance options.

The IHD/CAS shall consist of the following functional units which are illustrated in Figure 3 - 1:

Sensors
- X Band Radar
- S Band Radar
- Ka Band Radar (if applicable)
- HF Radar (if applicable)
- I.R.
- L.L.L.T.V.

Interfaces
- X Band Interface
- S Band Interface
- Ka Band Interface
- HF Interface
- Computer Interface
- Display Interface
- High Speed Serial Interface
- Electrical Power Interface
- T.V. Interface

Display
- High Resolution T.V. Monitor
- P.P.I.
- Operator Control Unit

Computer
- Display Processor

Processors
- X Band Signal Processor
- S Band Signal Processor
- Ka Band Signal Processor
- HF Signal Processor

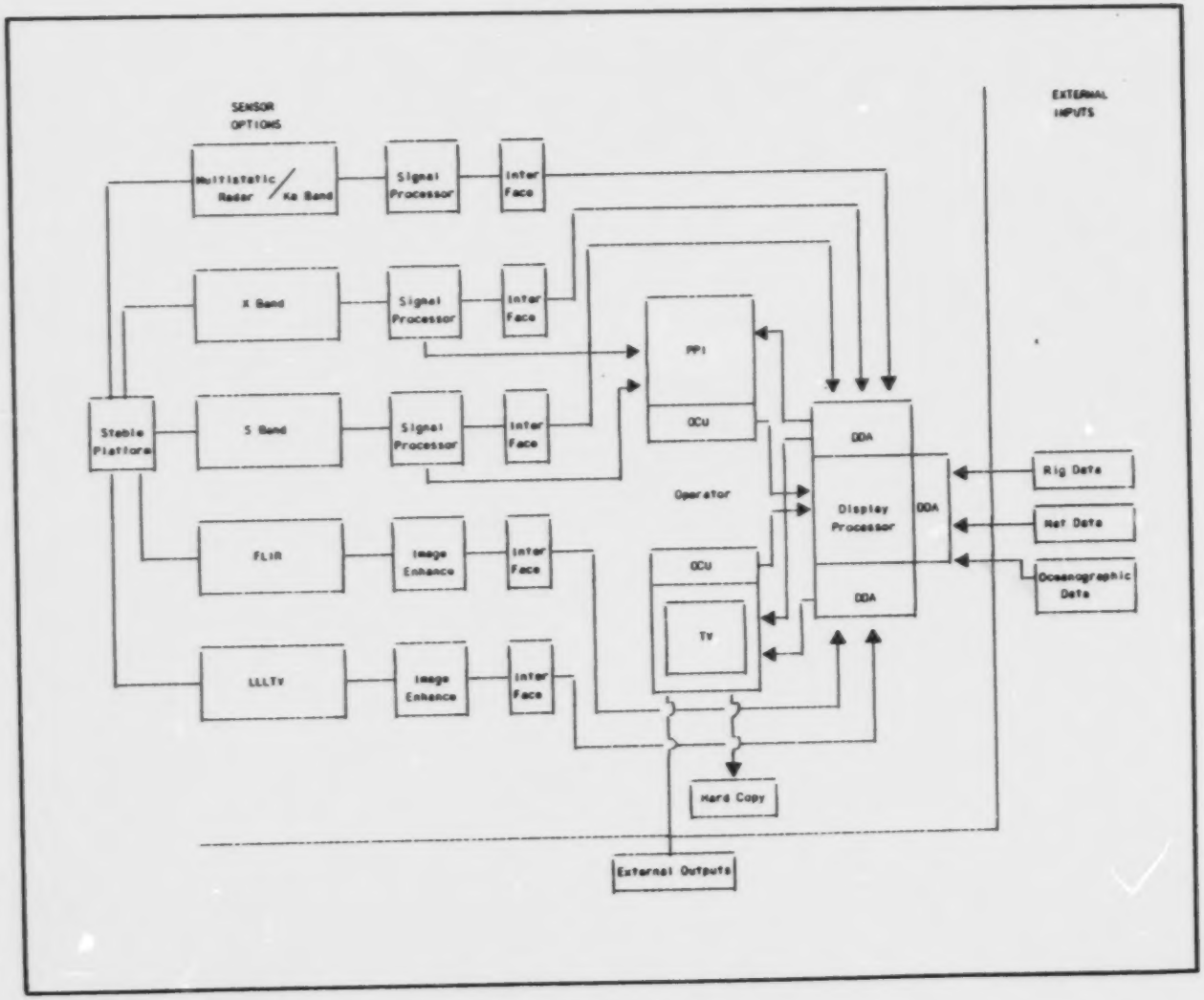


FIGURE 3.1

IHD/CAS BLOCK DIAGRAM

3.2 Sensors

3.2.1 X and S Band Radars

Both X and S Band radar are specified for their individual merits. The X-band radar is capable of finer spatial resolution and is capable of higher power levels near the ocean surface. X-band radar does suffer from signal attenuation due to heavy rainfall, and is prone to sea clutter problems. S-band radar has superior detection ranges due to lower frequency and generally higher power.

The following radars are specified as candidates for and IHD/CAS.

	Detection Range (km) Pd = .75 pfa = 10^{-6}	
	X Band	**S Band**
Raytheon	16	32
Japan Radio Co.	21	30
Japan Radio Co. Sea Ice Radar	31	
Furuno	19	
Sperry	25 Linear 14 Circular Polarization	
Racal Decca	29	31.5

Table 3.1
X and S Band Radar Capabilities [1]

1 Iceberg Detection Capability Part I, Newfoundland Petroleum Directorate Contract Report, 1983, p. 9

3.3 Interface Definition

3.3.1 External Display Interfaces

The display shall have external input interfaces to microwave radar, H.F. radar, T.V., computer and a high speed digital output interface for video.

The microwave radar interface shall use signals shown in Table 3.2.

SIGNAL	VOLTS	CHARACTERISTICS	PULSE WIDTH
Trigger 1 (A Scan)	TTL	0 to 5 KHz	100 ns min.
Trigger 2 (PPI, B Scan)	TTL	0 to 5 KHz	100 ns min.
Azimuth Clock Pulses	TTL	4,096 Hz	100 ns min.
Azimuth Reference Pulse	TTL	0 to 1 Hz	100 ns min.
Video PPI	0-2V	30 MHz	
Video A Scan	0-2V	30 MHz	

Table 3.2
Radar Interface Signals

The H.F. Radar interface shall use processed HF radar data for direct video presentation. This data will be accepted in a format suitable for a T.V. interface.

The display shall be capable of accepting T.V. video for line rates of 525, 625, and 875. Interface of 2:1 and 50 and 60 HZ field rates shall be accommodated.

The IHD/CAS shall interface with the external computer over a 16 bit parallel interface.

The display shall interface with digital video information over a 10M bit/second input channel. The protocol over this channel shall be such as to allow the transmitting sensor to set up the basic parameters of the scan, such as, scan direction, (up, down, left, right) line length, and starting position in the video area. Once this has been set up, pixel data may be sent continuously and the display formatting electronics shall automatically write the data into the correct locations.

3.3.2 Electric Power Interface

The display shall use 115 volts, 60 HZ, single phase.

The sensor shall use the following power requirements:

Microwave Radar - 440V 60 Hz 3 Phase
H.F. Radar - to be determined
L.L.L.T.V. - 120v 60Hz
I.R. - 120v 60Hz

3.3.3 Display Internal Interfaces

The display internal interfaces shall connect the following major items:

Display Driver Assembly to T.V. Monitor (Display Console)

Display Driver Assembly to Operator Contol Unit (OCU)

The display user is required to generate software for each application of the display. This software will execute in the display processor. To simplify the user software, display software modules shall be provided which perform basic functions for scheduling and interfacing between user software, the display driver assembly and the sensor processors.

The display processor shall include provision for the sounding of an audible alarm under user software control.

Control of the display and selection of its functions shall be performed by the display processor using the commands defined for the display driver software. These commands fall into four categories:

O.C.U. and T.V. Monitor
Video Processing and Display Functions
Graphics/Track Management Functions
Status/Test Functions

3.3.4 Display Processor

The display driver assembly shall interface with a computer,designated the Display Processor. The computer shall perform display processing applications functions, under user generated software control.

All sensors shall incorporate the most effective signal processing techniques for the particular sensor in question.

Standard rain and sea clutter processing features such as FTC and STC shall be implemented. Constant false alarm rate (CFAR) capability shall be considered. CFAR techniques do not necessarily improve signal to clutter ratios, but ensure that the best signal to clutter ratio is available. Therefore, all techniques that improve the signal to clutter should be considered. At present the Japan Radio Corporation Sea Ice Radar offers true signal to clutter ratio enhancement and utilizes scan to scan correlation to accomplish this. Techniques utilized by McGill University shall be investigated and incorporated if they prove superior to the J.R.C. system. In principle, any number of images may be averaged, but care must be taken to ensure that targets have not moved too far in the time interval from the first to the last image. Unless the target is stationary, averaging over longer time periods will probably degrade target size, shape and intensity proportional to the time period itself and the speed of the target. Long term averaging, will in fact, eliminate stationary targets such as ice.

3.4 Functional Characteristics

The colour T.V. monitor shall be a medium resolution device.

The Operator Control Unit (O.C.U.) will consist of a control panel connected to a chassis. The purpose of the O.C.U. is to allow system control.

A trackball shall be provided, of a size between 2" and 3".

A 3" square touch panel shall be provided off-screen.

A standard keyboard shall be provided. The ASCII code associated with each character or control function is transmitted to the Display Processor on selection.

A total of 7 momentary contact Q.E.B.'s shall be provided. These buttons shall be used for standard functions and three shall have unassigned functions. Each Q.E.B. shall contain a lamp which shall be activated by the Display Processor. The three lamp states are:

On
Off
Blink

There shall be an indicator lamp marked BITE FAIL. This will be driven by an automatic fault monitor attached to the Console Controller in the O.C.U.

There shall be a lighted pushbutton marked BITE, which when pressed, will initiate the BITE routine. The lamp will be lit while the routine is in progress and will extinguish upon completion. A fault detected by BITE will cause a lamp marked BITE FAIL to be latched on. The BITE process shall be initiated by the Display Processor on recognition of the button press.

Five rotary controls shall be provided to perform the following functions:

Graphic brightness
Video brightness
Trackball cursor brightness
Radar threshold
Audio Alarm Volume

A lighted pushbutton switch shall be provided to switch power to the electronics units.

3.5 Video Processing & Display Functional Characteristics

3.5.1 Display Format

The IHD/CAS shall have two separate memories. Sensor video information shall use a video memory of 512 x 512 picture cells (pixels) with each pixel having 4 bits for intensity. Sensor video colour shall not be dynamically selectable. Characters and graphics shall use a graphics memory covering the full extent of the 625-line raster (585 lines at 761 pixels/line) with each pixel providing a colour shade (of single intensity) defined by 4-bits, ie. 1-bit for each of the three primary colours and one bit for BLINK. The video area shall be controlled in size (up to a maximum of 512 x 512) and position within the complete raster by the Display Processor.

3.5.2 Radar Processing and Display

The digitizer shall accept radar trigger, radar video and binary azimuth information. The radar video shall be digitized to a resolution of 8 bits giving 256 levels of signal intensity. The sample rate shall be great enough to prevent aliasing when digitizing data with a 50 ns pulse width.

A radar video threshold control shall be supplied on the O.C.U., that shall control the offset value of the video imput to the A/D converter.

The digitized radar video shall be filtered in range and azimuth. Range filtering techniques will be determined using modern techniques under development.

In the P.P.I. mode the selected radar shall be displayed in the video area. The offset and scale of the radar shall be provided by the Display Processor in external units (data miles), relative to the Display Reference Coordinate.

(a) Range Scales: Range scales in binary increments from .5 data miles to 256 data miles (ie. maximum coverage shall be 128 data miles).

(b) Offset: The P.P.I. display shall be capable of being offset anywhere within the 256 mile square coverage. Offsets of 1.5 times selected range scale shall be permitted without spoking of the video.

(c) A P.P.I. display displaying analog radar video shall complement the digital display.

3.5.3 Framing Sensor Processing and Display

The IHD/CAS shall interface with Framing T.V. tape video, with lines per frame selected as 525, 625, and 875. The IHD/CAS logic shall perform A/D conversion and store the T.V. video information in the video memory, thus permitting annotation, external image processing by the Display Processor.

Imagery that falls outside the 512 by 512 video area shall not be displayed.

The video shall be digitized to 8 bits. A level-slice table loaded from the Display Processor shall reduce this to 4 bits prior to entry into the video memory. A linear transfer function shall be set into the table as a default condition on power-up.

3.5.4 Line Scan Sensor Display

The IHD/CAS shall provide a High Speed Serial Interface with a maximum input data rate of 10 MHZ and a protocal to accept digitized video and load it directly into the video memory. The protocal shall be such that, for line scan formats, maximum use shall be made of the bandwidth of the digital channel for data transmission.

3.5.5 Video Memory Scrolling

The video memory shall be scrolled in Y independently of the graphics memory by specifying the Y address of the memory line desired at the top of the raster. This position shall be specified to a resolution of 4 lines.

3.5.6 Scan to Scan Integration

The scan to scan integration techniques which consist of averaging the data at each cartesian pixel over several successive images shall be considered. The number of images shall be variable and determined by the operator.

An equation which could be used is shown here

$$S_{n+1} = S_n + \frac{1}{2^k} (X_{n+1} - S_n)$$

where S_{n+1} is the new sample to be stored in video memory

S_n is the old sample from memory

X_{n+1} is the new input sample from the sensor

K is the filter time constant

Much more advanced algorithms under development should be considered.

3.5.7 Target Trails

On selection, target trails shall be implemented by combining video data from a new scan with video data from the previous scan such that

$$S_{n+1} = X_{n+1} \quad \text{if} \quad X_{n+1} > S_n$$

$$\text{else} \quad S_{n+1} = S_n + \frac{1}{2^k}(X_{n+1} - S_n)$$

3.6 Graphics & Target File Management Requirements

3.6.1 General

This IHD/CAS shall be capable of displaying graphics anywhere within the limits of the 625 line T.V. raster at full resolution. The graphics memory shall therefore be a minimum of 585 lines x 761 pixels/line.

A capability to incorporate brightness levels shall be incorporated in the graphics memory shall be 4 bits deep, giving the capability of off, high brightness and blink, for any of the three colours and their combinations.

The blink rate shall be 1 Hz, with on-off ratio 1 : 1

The IHD/CAS shall have the capability of drawing ASCII characters, selected symbolic characters, vectors, arcs and circles in both positive and inverted video format. It shall also allow user defined line tapes and character set. Graphics shall be overlayable without loss of information.

The full 64 character set of displayable ASCII characters shall be implemented. Two character sizes shall be provided as shown in Table 3.3.

Type	Matrix Pixels	Character Size Pixels	Character Size in Inches
Small	6 x 11	4 x 6	.07 x .11
Large	10 x 15	6 x 8	.11 x .15

TABLE 3.3
IHD/CAS MATRICES ASCII

The IHD/CAS shall be capable of drawing vectors and strings of vectors of any length and slope. The vectors shall be defined in two ways; by the end points; or by the start points plus length and slope.

The IHD/CAS shall be capable of drawing arcs of any radius and angular subtense, up to full circles. A full circle may be drawn by making the angular subtense 360 degrees.

The lines constituting the vectors and circles shall be 1 pixel wide. One of two line types shall be selectable. These types are continuous or dashed.

The possible character symbology shown in table 3.5 may be implemented. Two symbol sizes shall be provided as shown in table 3.4.

Type	Symbol Matrix Pixels	Symbol Size Pixels	Symbol Size Inches (19 in T.V.)	Subtense at 18 inches (min. of arc)
Small	9 x 9	8 x 8	.15	29' x 29'
Large	12 x 12	11 x 11	.20	39' x 39'

TABLE 3.4
IHD/CAS MATRICES USER PROGRAMMABLE

3.6.2 Graphics Addressing

Graphics parameters (position, length, etc.) shall be defined in two alternate coordinate systems, pixel coordinates (internal or display units) and data mile (dm) coordinates (external units). In the latter case the graphics position shall be relative to a Display Reference Coordinate (DRC). The position of the display raster shall therefore also be defined in data miles, relative to the DRC.

The smallest piece of graphics that can be identified (line, character, etc.) shall be called an Entity. A graphics Entity may be enabled, moved, suppressed or change intensity, but components of the entity may not be altered independently of other components of that entity.

All displayable graphics data shall be defined in Tag blocks and may be moved, deleted, or altered by reference to the tag block number. A total of 250 tags shall be definable. A maximum of 25 entities may be specified within one tag. The maximum tag length shall be 128 words.

Tags shall be maintained in a Display File. The Display shall be periodically refreshed from this file to eliminate pinholding caused by the movement of intersecting entities. The Display File shall be large enough to accommodate the graphics load in table 3.6, which requires approximately 10 K words.

TABLE 3.5
USER PROGRAMMABLE SYMBOLOGY EXAMPLES

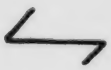
	Ice Edge
	Iceberg
	Hazard (Blinks)
	Reference Point
	Charted wreck
	Helicopter
	Reference Point
	Fix
	Ownship
	Surface Ship
	Ball tab

TABLE 3.6
GRAPHICS LOAD

ITEM		QUANTITY
1	Dynamic tracks	140
2	Static tracks	120
3	Closest point of approach and intercept vectors and symbol.	30
4	General pupose lines	10
5	Relative bearing lines	5
6	Utility circles	5
7	Mapping vectors, average length 64 pixels	136
8	Alphanumeric text characters	150
9	Predicted target motion paths average length 256 pixels.	20

The Display shall be capable of windowing. The Display Processor shall define a rectangular field of view within the full graphics raster within which entities whose base position is defined in data miles shall be windowed. For most applications, this field of view shall be the same as the video overlay area up to the maximum 512 x 512 pixels, although graphics - only applications may define the full raster (761 x 585) as the external - unit field of view. Entities defined in pixels shall be windowed by the raster. Those portions of all entities that fall within the defined window shall be displayed except for characters and symbols, when the entire symbol matrix must lie within the field of view for the symbol to be drawn.

The principle of operation is shown in figure 3.7. It should be noted that the IHD/CAS Function Generator shall only compute addresses within the window. Out of bound addresses shall not be computed in order to minimize the total time taken.

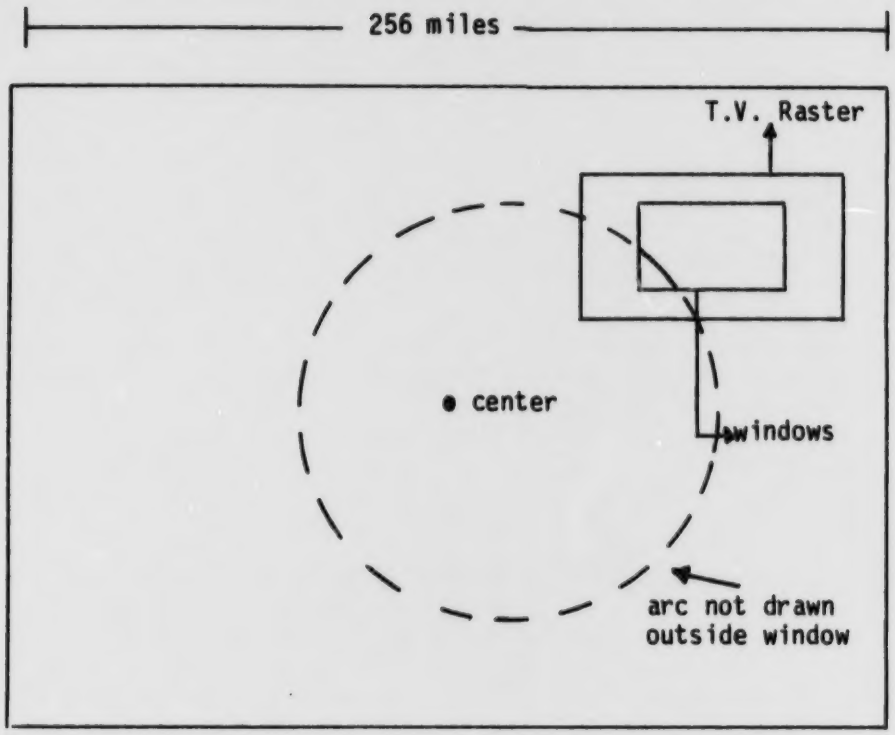


Figure 3.7
WINDOWING

3.6.3 Graphics Magnification

A graphics magnification of two and four times shall be provided.

3.6.4 Cursor

A trackball cursor symbol and cursor control shall be provided.

This cursor shall be contrained to move within the video graphics field of view under Display Processor Control. The cursor shall be positioned either by the trackball or the Display Processor. The cursor shall be selectable from a number of types by the Display Processor as follows:

a) Ball Tab Cursor
b) Horizontal Line Cursor
c) Vertical Line Cursor

The horizontal and vertical line cursors may be enabled independently or together.

3.7 Physical Characteristics

The IHD/CAS shall consist of the following physical units:

Display Drive Unit
Power Supply Unit
TV Monitor
Operator Control Unit
PPI
Display Processor

X Band Radar Antenna Assembly
X Band Power Supply
X Band Transmitter
X Band Receiver
X Band Sync and Signal Junction Box

S Band Radar Antenna Assembly
S Band Power Supply
S Band Transmitter
S Band Receiver
S Band Sync and Signal Junction Box

Ka Band Radar Antenna Assembly
Ka Band Power Supply
Ka Band Transmitter
Ka Band Receiver
Ka Band Sync and Signal Junction Box

} if applicable

HF Radar Antenna Assembly
HF Power Supply
HF Transmitter
HF Receiver
HF Sync and Signal Junction Box
} if applicable

IR Scanner
IR Photo Section
IR Analog Section
IR Digital Section
IR Heavy duty Tripod
IR Remote pan/tilt controller
IR Liquid nitrogen container

LLLTV Scanner
LLLTV Photo Section
LLLTV Analog Section
LLLTV Digital Section
LLLTV Heavy duty tripod
LLLTV Remote pan/tilt controller

The following units shall consist of 19 inch rack mountable modules.

Display Drive Unit
Power Supply Unit for Display Processor
Display Processor
X, S, Ka, HF Band Power Supply
X, S, Ka, HF Band Transmitter
X, S, Ka, HF Band Receiver
X, S, Ka, HF Band Sync and Signal Junction Box
IR, LLLTV Analog Section
IR, LLLTV Digital Section
IR, LLLTV Remote Pan and Tilt Controller

The TV monitor shall be a 24 inch rack mountable set. The TV monitor, PPI and Operator Control Unit shall be located on the bridge or in the vicinity of the bridge.

The TV Monitor, PPI and OCU shall be capable of 100m separation from the Display Drive Unit. All interfaces shall be capable of operating over 100m using TRF-58 cable.

3.8 Reliability

3.8.1 Quantitative Reliability Requirements

The specified MTBF for the IHD/CAS shall not be less than 500 hours when operated under the environmental conditions specified.

The contractor shall implement an effective reliability program.

The mean corrective maintenance time (Mct) to repair the IHD/CAS shall not be greater than 45 minutes. The maximum corrective maintenance time shall be less than 2 hours at the 90th percentile.

3.8.2 Preventive Maintenance

Preventive maintenance of the IHD/CAS shall be limited to TV and PPI monitor adjustments, the replacement of air filters and lubrication of rotating sensor equipment.

All modules of the IHD/CAS shall be accessible.

3.8.3 Environmental Conditions

As specified in the preliminary specification for the IHD/CAS, the system sensors and external components will be capable of withstanding the extremes of the arctic climate.

The internal components of the IHD/CAS shall conform to the operating temperature conditions of range 4 of MIL-E-16400.

The IHD/CAS shall be capable of extended storage within the non-operating range specified in MIL-E-16400 (-62°C to 71°C) when the IHD/CAS is removed from storage to the operating temperature range the equipment shall operate correctly with no mechanical or electrical damage.

3.8.4 Vibration

The IHD/CAS shall be capable of withstanding the type 1 vibration test of MIL-STD-167. Equipment which is rack mounted shall be tested as a complete unit in order to simulate actual shipboard conditions.

3.8.5 Humidity

The IHD/CAS shall be capable of withstanding the humidity requirements as specified in MIL-E-16400.

3.8.6 Transportability

The IHD/CAS equipment shall be capable of sufficient disassembly to allow shipping by commercial and ground carriers. After reassembly no servicing or realignment shall be required for correct operation.

3.9 Quality Assurance

3.9.1 Workmanship

The IHD/CAS will be manufactured in accordance with published workmanship standards of the manufacturer.

3.10 System Testing

3.10.1 Functional Testing

Thorough functional testing of the IHD/CAS will be conducted during the engineering program. This may make use of pre-recorded sensor data collected during the Petro Canada/TDC field trials conducted in 1981.

A test, analyze and fix program will be performed.

3.10.2 Environmental Testing

A formal test plan and report will be conducted.

The following tests will be performed:

(i) Temperature: per Mil-E-16400G (method 501 and 502 of MIL-STD-810)

(ii) Humidity: per MIL-E-16400G (method 507, procedure IV of MIL-STD-810)

(iii) Vibration: per MIL-STD-167, type 1

3.10.3 Acceptance Tests

A test plan will be prepared by the contractor to display compliance with the functional specification.

4. Development Programs and Time Scales

The following programs are intended to illustrate some of the Canadian development underway in high technology areas. These programs are suitable for either consideration as components of an overall IHD/CAS system or as potential sources of information when formulating plans and requirements for such a system. The listing of programs is complete as far as Canadian surface-borne ice and iceberg detection work is concerned.

Many of the development programs are ongoing, however, target dates for some useable systems are presented. These dates will coincide with the advent of east coast production facilities (1987-1990) and will precede the installation of production facilities in the Canadian and Beaufort Sea (1988-1992) and High Arctic (1990's). As long as IHD/CAS system development progresses and parallels these activies, there is no reason to believe that an integrated system could not be made available by 1987. Any system produced before such a time would have the added advantage of having been given the opportunity to be trialled on an exploration platform on the east coast or Beaufort Sea or on a merchant ships such as the M.V. Arctic.

4.1 Industry Sponsored Development Programs

4.1.1 Gulf Oil Exploration and Production Company Program to Develop Coastal Ocean Dynamics Applications Radar for Offshore, Wave, Current and Wind Monitoring

4.1.1.1 Introduction

A project initiated by Gulf Oil to adapt HF radar (called CODAR) for use from offshore platforms is approximately half completed.

Analyses since the work completed by Crombie [2] has established the relationship between higher-order sea echo and the waveheight directional spectrum.

HF radars are characterized by their long wavelength (in contrast with more familiar microwave radars), and hence the required large antenna sizes if conventional beamforming methods are employed. Because of the problems posed by large antennas for most wave and current measurement applications, NOAA (National Oceanic & Atmospheric Administration) began a program to develop and demonstrate compact, HF coastal radars that could make these measurements in near-real time. Several experiments proved that such systems were feasible and accurate.

4.1.1.2 The Program

In 1982 Gulf Oil Exploration and Production Company began a program to adapt the CODAR technology developed by NOAA to deployment from platforms, both for its own far-reaching offshore operations and for the use of the oil industry as a whole. The project is defined to comprise the use of a crossed-loop/monopole antenna system (to be discussed below) with a disk-based, PDP 11/23-controlled CODAR data acquisition system to produce real-time waveheight directional spectra, surface-current vectors, and surface-wind vectors.

The Gulf CODAR/WDS project includes both software and hardware adaptation and optimization; companies involved directly in this venture with Gulf are Ocean Surface Research for the software and Codar Technology, Inc. for the hardware. The project will include several tests of the system from platforms, supported by observations of surface conditions by other instrumentation. By mid-1984 the Gulf CODAR/WDS project will be completed, with prototypes of the system being available at that point.

4.1.1.3 Hardware Status

Before beginning the Gulf CODAR/WDS project, much of the hardware involved in this system had already been engineered for operational use; this was done under a NOAA program called CODAR Transitional Engineering. At present, all of these essential elements of the CODAR unit have been assembled and lab tested.

Hardware items of specific relevance to the Gulf CODAR/WDS project are presently being completed and integrated into the system. These include a Winchester disk, array processor, new signal-processing interface board, switches, and phase shifters to handle the transmit beam-steering, and the new loop antenna itself.

A major part of the effort centers on antenna development and associated switching/phase-shifting. In early 1984, the antenna is to be adapted to receive on 5MHz, in addition to the present 25MHz.

Although several hardware items are still under development and optimization, it should be emphasized that a working system presently exists for Gulf CODAR/WDS purposes.

4.1.1.4 The Future

A series of tests from platforms are planned. The first is in the Spring of 1983, from a fixed platform in the Gulf of Mexico; this will provide data to complete and refine existing software. Tests in the North Sea are envisioned during the Winter of 1983-1984, from semi-submersibles. As these milestone tests progress, the configuration of the system and software will be finalized. By mid-1984, a prototype of the Gulf CODAR/WDS operational system will be completed.

The system presently is not optimized to detect ice or process ice information, however, the lack of doppler shift and thus the obvious absence of surface current vectors would indicate the presence of ice or icebergs. This would enable the system to be used as an ice detection sensor as well. It's limited range at present and extensive data processing requirements may not permit its use as an effective ice management tool. The present studies underway at C-Core use the same basic equipment and to date have been more concerned with ice and iceberg detection. Again however, the CODAR system suffers the same problem of limited range and resolution.

4.1.2 Mobil Oil Canada, Canterra Energy Ltd., and Petro Canada Exploration. Specification Development and Prototype Hardware Design for a Multistatic Surface to Surface Radar System.

4.1.2.1 Introduction

Mobil, Canterra and Petro Canada are currently sponsoring the development by the Batelle Columbus Laboratories of a Sea Ice and Iceberg Detection Monitoring System utilizing a Multistatic Radar System.

Recently, Battelle's Columbus Laboratories completed a study on a bistatic radar system for detection and monitoring sea ice and icebergs. This was a preliminary study conducted to provide background for a longer-range research program.

In the preliminary phase, the technical and operational trade-offs of various bistatic and multistatic radar system concepts using aircraft, helicopter and surface-to-surface platforms were conducted. The analysis showed that the surface-to-surface system provides the best ice detection capability and has all weather capability, it was selected by the current sponsoring companies as the most desirable approach.

4.1.2.2 System Concept

In a multistatic surface-to-surface system, the transmitters can be placed on buoys and/or ships and the receiver can be on the drill rig.

Figure 4.1 shows a typical system geometry with two transmitters. The ellipses correspond to curves of constant range (transmitter to receiver) which are identified in the radar signal by time delays at the receiver. The use of multiple transmitters allows the location of ice cells in both range and azimuth.

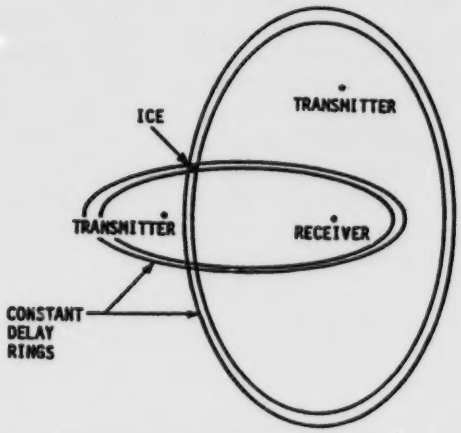


FIGURE 4.1 CONSTANT DELAY CONTOURS FOR SURFACE-TO-SURFACE SYSTEM

For the multistatic surface-to-surface geometry selected, the high frequency (HF) region will be utilized between 50 and 500 MHz. Several advantages are stated. This will permit electromagnetic waves of high frequency systems to propagate over the curvature of the Earth, thus extending the range several times over that possible by microwave radars. Ranges of 100km with a 10m x 10m resolution will be possible.

It will also enable separation of ice from water. In addition, the surface-to-surface system using high frequency electromagnetic waves will allow the separation of ice objects from water on a unique basis.

At HF, ice objects are of the order of the wavelength, eg., a 10m object corresponds to 30 MHz resonant frequency. As a result, the entire object is polarized, thus radiating nearly isotropically rather than discrete specular reflection as in microwave systems.

Transmitting antennas can be simple monopole whips.

Simple data displays (eg. ice, or no ice) that require no special operator skill, nor sophisticated interpretations will be produced.

4.1.2.3 Research Plan

The research activities to be conducted are described in six tasks outlined below.

4.1.2.3.1 Review and Upgrade Ice Measurement Parameters

Additional available information on sea ice will be obtained to enhance system performance, eg. statistics of floes and bergs, brine content, ice morphology, etc. This information will be incorporated into an expanded ice model.

4.1.2.3.2 Review and Detail Operational Environment and Platform Interation with System Design

During this task, the dynamics and environmental factors associated with potential transmitter platforms (fixed, ships and buoys) will be examined to assess the potential impact on the system performance and to develop mitigation techniques, if required.

4.1.2.3.3 Design Analysis

The analysis of the surface-to-surface system initiated earlier will be extended and updated to include detailed radiated waveform characteristics, various signal processing algorithms, and development of the coordinate conversion operations to reference the elliptical system coordinates to an operator centered display format. The extended computer model will then be used to optimize the system parameters. The specific activities include:

- Update mathematics model for surface-to-surface system, including coordinate transformation so that the operator will be in the center of coverage area.
- Computer model updating.
- Waveform definition
- Signal processing algorithm definition.
- Optimization

4.1.2.3.4 Establish Design Specifications

Based on the design analysis and optimization of the above task, the design specifications for the various system elements will be generated. These will be in sufficient detail so as to allow subsystem design and/or puchase to be accomplished.

4.1.2.3.5 Prototype Hardware Design

Based on the design specifications generated from the above task, design of the hardware for a prototype system will be conducted. This will include functional layouts for all subsystems, design schematics for subsystems to be fabricated, including component identification and values, input/output signal parameter identification and values for all subsystems, including power requirements, and specifications for all subsystems to be purchased.

The subsystems to be designed include:

- Transmitter unit
- Receiver
- Signal Processor
- Data Processor, including
  - Ice/water detector
  - Ice locator
  - Track generator
  - Track file/monitor
  - Coordinate converter
  - Display driver
  - Memory
- Data Recorder
- Display unit, including
  - Visual display
  - Alarm Generator
  - Hard copy generator
- System controller
- Power supply

4.1.2.3.6 Identify Components to be Procured

The subsystems and components to be purchased will be identified as based upon detailed specifications which are generated during the previous task. This activity will include identifying sources of suitable components and subsystems, prices, and delivery times.

4.1.2.4 Schedule and Costs

The current program will span from September 1982 until approximately May or June 1983. On completion, a decision will be made by the partners with regard to follow on programs. It is expected that the next phase of the program will be undertaken to manufacture a prototype. This phase is expected to cost in the order of $300,000 dollars and take approximately one year to complete.

The system shows the potential to fill the requirements for long range surface based ice detection on the east coast. It is being designed and constructed principally for use aboard semi submersible drilling platforms, with each platform utilizing a single system, and operating in conjunction with other platforms in the vicinity. At present, the major problem to be overcome will be the elimination of false targets due to lobing through processing.

4.1.3 Mobil Oil Canada Ltd., Hibernia Iceberg Detection

4.1.3.1 Introduction

Mobil has contracted a consortium of companies to conduct a review of all methods and instrumentation for iceberg detection. This will include specifying the existing limitations and discussing possible improvements to increase the range and ability to these methods to detect icebergs. Mobil's ultimate goal will be to develop a system for iceberg detection "within 100% reliabilty" [3].

4.1.3.2 Details of Work

All systems presently in use are to be investigated. In addition, all systems which could be used with further development will be investigated. This will include various synthetic aperture radars and bottom mounted sonars. Thus it is an all encompassing study of ice detection capabilities including strategic and tactical ship mounted ice detection system.

Mobil plans include reviewing all instrumentation for availability and historical user with regard to iceberg detection. Equipment costs and operating limitations are to be considered.

Mobil will employ a system type of approach to "develop and iceberg detection package of primary and secondary instrumentation for as close to 100% detection as possible."

4.1.3.3 Costs and Schedule

It is expected that work on the project is to commence in July 1983. Mobil will have the project completed in eight months. The expected value of this investigation is in the order of between two and three hundred thousand dollars.

4.1.3.4 Future Plans

On completion of this contract, it is expected that Mobil will conduct four more phases of development to produce an effective IHD/CAS for the Hibernia operations by 1987.

4.1.4 Japan Radio Corporation

4.1.4.1 Introduction

The Japan Radio Company (JRC) is a world leader in radar technology. JRC offers a sea ice detection system using highly advanced technology and includes sophisticated computer utilized image processing and statistical processing. The results are displayed on a colour bright display.

4.1.4.2 The Program

The Sea Ice Research Laboratory of Hokkaido University has conducted radar research on drift ice since 1966 [4]. In 1977, J.R.C. supplied a sea ice radar signal processor and radar where trials and improvements were made. Figure 4.2 and 4.3 illustrate these improvements.

4.1.4.3 Signal Processing

The J.R.C. sea ice signal processor incorporates standard rain and sea clutter processing feature in the radar hardware with computer control. This optimizes detection thresholds to obtain the best signal to clutter ratio. A constant false alarm rate performance is obtained for each radar resolution cell, however, futher CFAR processing will not improve signal to clutter ratios.

The sea ice signal processor is capable of scan to scan correlation. Using recursive scan correlation and other techniques J.R.C. claims a 15 dB improvement in signal to clutter ratio. However, an analysis done by the Newfoundland and Labrador Petroleum Directorate (NLPD) indicates that a maximum improvement of 7.5 dB is possible [5]. This discrepancy may be due to the fact that J.R.C. has based this 15 dB improvement on work done by the Japanese Institute of Navigation in a paper entitled, "Statistical Properties and the Suppression of Radar Sea Clutter". This paper claims a 7.0 dB improvement in signal to clutter ratios due to CFAR circuits. However, the NLPD report claims CFAR processing will not improve signal to clutter ratios in the J.R.C. system. This discrepancy is not insignificant , but should not prejudice considerations for implementing J.R.C. methods of signal processing in future ice hazard detection systems. The J.R.C. sea ice signal processor is probably the most technically advanced system for surface-borne ice detection and iceberg on the market today.

[5] Iceberg Dection Capability Part I, Newfoundland and Labrador Petroleum Directorate Contract Report, 1983, p.27.

Two small boats are masked by sea clutter.

Fig. 4.2 Heavy sea clutter condition

Reprinted from an article entitled "Sea Ice Detection Radar" by the Japan Radio Co. Ltd. 1982.

Processing functions are on in a sectorial area, and sea clutter is eliminated, revealing two boats in the area.

Fig. 4.3 Detectability enhanced

Reprinted from an article entitled "Sea Ice Detection Radar" by the Japan Radio Co. Ltd., 1982

4.2 Government Sponsored Development Programs

4.2.1 Canadian Coast Guard, Department of Transport Sponsored research conducted by Prof. G.L. Austin and G.H. Ballantyne at the McGill Radar Weather Observatory 6

4.2.1.1 Introduction

The shore-based marine radars presently operated by the Canadian Coast Guard and others generate, as a minimum for each 3 second rotation of the antenna, approximately 1500 independent azimuths and approximately 1000 independent range cells for each azimuth. If the total amount of information per atenna rotation is about 6 Mbits.

When these data are required at a site remote from the radar, present practice has been to send the information on a microwave link.

If it is required to use, in place of the microwave links, much lower-capacity telephone lines with, for example, 10 kHz (or 9600 baud) bandwidth, then clearly some changes will have to be made.

The first and perhaps most important change is to use nonfading display technology so that the images only have to be updated when significant movement of the target is likely to have occurred. This reduction in update time would still require a bandwidth of about 200 kHz.

The present work has as one of its objectives the development of a transmission and data processing methodology which will allow a further bandwidth reduction from 200 to 10 kHz.

The strategy was to eliminate all nonessential information from the display and then to transmit that portion of the image actually required, with absolutely no reduction of image quality.

4.2.1.2 System Hardware

Radar data were collected from the McGill Weather Radar which was modified to achieve closer resemblance to a marine radar.

The prototype digitizer accepted radar trigger, log video and binary azimuth information.

The processing hardware used to record the data was a Digital Equipment Corporation (DEC) LSI-11/23.

4.2.1.3 System Processing

Land overlays were required for the bandwidth reduction strategy. These overlays allowed software to ignore land clutter.

Having produced a file of Cartesian images for the Seaway region and the appropriate land overlays, bandwidth reduction software analysis could commence.

Four coding techniques were actually tried, i.e. nonzero, run length, frame comparison and scan-to-scan averaging. The scan-to-scan averaging technique consists of averaging the data at each Cartesian pixel over several successive images. The number of images is variable. This technique was employed to address the problem of sea clutter in the radar video both as it affects transmission timing and as it masks real marine targets on the operator's display. The scan-to-scan average must read up to four displays and write the average back onto the display.

4.2.1.4 Results and Conclusions

There is little noise in images and no weather or sea clutter.

High noise levels present a different problem in that no amount of averaging can reduce clutter echoes to subtarget levels. This poses well understood radar problem for the operator in that he must attempt to retrieve target information from a display which has lost some of its intensity information. In this severe case, update times may not be as important as identifying vessels in high-intensity sea clutter, and so the operator might choose a combination of variable or fixed averaging and thesholding to clear up the image, and thus better delineate real targets.

It is demonstrated that the averaging of four successive scans taken 10 s apart significantly reduced the adverse effects of simulated sea clutter, both on image clarity and transmission time.

4.2.2 Communication Research Laboratory - McMaster University, Hamilton, Ontario

4.2.2.1 Introduction

In 1982 the CRL received a strategic grant from the Natural Sciences and Engineering Research Council of approximately $750,000.00 dollars to proceed to develop coherent radars for ice classification and detection. The emphasis of this work will be placed on the development of tactical forward-looking radars to be mounted on Arctic going vessels. Engineering and technical support is also being provided to the Department of Fisheries and Oceans Radar Research Program. This contract value is $21,031.00 dollars.

4.2.2.2 Programs

The development program proposed by CRL calls for design periods and field experiments over the next four years with a commercial system to be available by 1988.

In the fall of this year the CRL will conduct a field program in the Arctic utilizing their X-band radar system. The primary objective of this experiment is to investigate the ability of this system to image sea ice and to develop an ice data base. Data from iceberg targets will be collected on an opportunity basis.

The CRL development program is two-sided with both hardware (new radar) development and signal processing development providing for a program which will specifically be suited to ice classification and detection.

4.2.3.3. Hardware

Presently, CRL has on order the necessary components to build an X-band coherent radar. The radar antenna will be a sampled array structure allowing for the optimization of the azimuth beamwidth to particular environmental conditions. The transmitter will be capable of pulse compression on the order of 1:10 so as to increase range resolution and allow for optimization of the range resolution cell size.

4.2.2.4 Processing

The CRL hopes to apply their past experience in extracting targets from weather and ground clutter to the problem of iceberg detection in a sea clutter environment. Their present unreleased work on ground and weather clutter processing promises to provide significantly better clutter rejection than any other available method.

In addition, researchers at CRL are also developing a model for use in prediction of amplitude and cross-polarization of the return signals from basic iceberg shapes.

4.2.3 Department of Engineering/Center for Cold Ocean Resources Engineering (C-Core)
Memorial University of Newfoundland (MUN)

Development of an HF Radar for the Detection of Iceberg Targets in a Rough Sea

4.2.3.1 Introduction

Supported by financing from the Department of Fisheries and Oceans and the Natural Sciences and Engineering Research Council, the MUN research team has concluded from their theoretical work that HF radar will detect ice edges and icebergs beyond the normal radar horizon (typically 20 - 30 km. Based on this theoretical work the research emphasis is being placed on a mono-static HF radar system with a highly directional antenna to eliminate second-order scatter effects.

4.2.3.2 Program

The MUN/C-CORE team has recently completed a field program to confirm this theoretical work.

The next stage of this program is to carry out a large scale iceberg detection/data collection experiment which will help to identify critical operating parameters such as beamwidth, frequency and transmitter power and the utility of developed processing techniques. Presently, the funding for this stage of the program is not in place, however, efforts are being directed to this end.

It is envisaged that this configuration of HF radar will provide the basis for the development of a total East Coast Ocean Monitoring System capable of providing:

- iceberg, sea ice detection and tracking.
- ship traffic management
- ocean surface monitoring
  - surface current
  - wave height spectrum

4.2.3.3 Hardware

The MUN/C-CORE group own and operate a CODAR HF radar system.

4.2.3.4 Processing

Signal processing goals of this group are in the area of enhancement of the detection of small ice targets in the presence of noise and sea clutter.

5. Radar Data Assessment

5.1 Introduction

In order to evaluate the collected data the laboratory system used by Remotec Applications Inc. was assembled at Viatec facilties with the aid of Remotec staff. Several system problems were identified and corrected before the data evaluation was commenced. The data evaluation was carried out in two parts. The first part consisted of an elimination of the targets which were unsuitable for subsequent evaluation. These unsuitable events were eliminated due to either technical problems which occurred at the time of collection or inadequate ground truth data being available or recorded for specific targets. The second part of the evaluation consisted of a preliminary analysis of the reduced data set. The preliminary analysis serves to identify the types of radar parameter comparisons which can be made with this reduced data set and hence the utility of the data set for drawing conclusions on particular radar parameter combinations to optimize iceberg detection.

5.2 System Configuration Problems

The system developed and used by REMOTEC for reproducing and analyzing radar signals reflected from ice targets was configured as shown in Figure 5.1

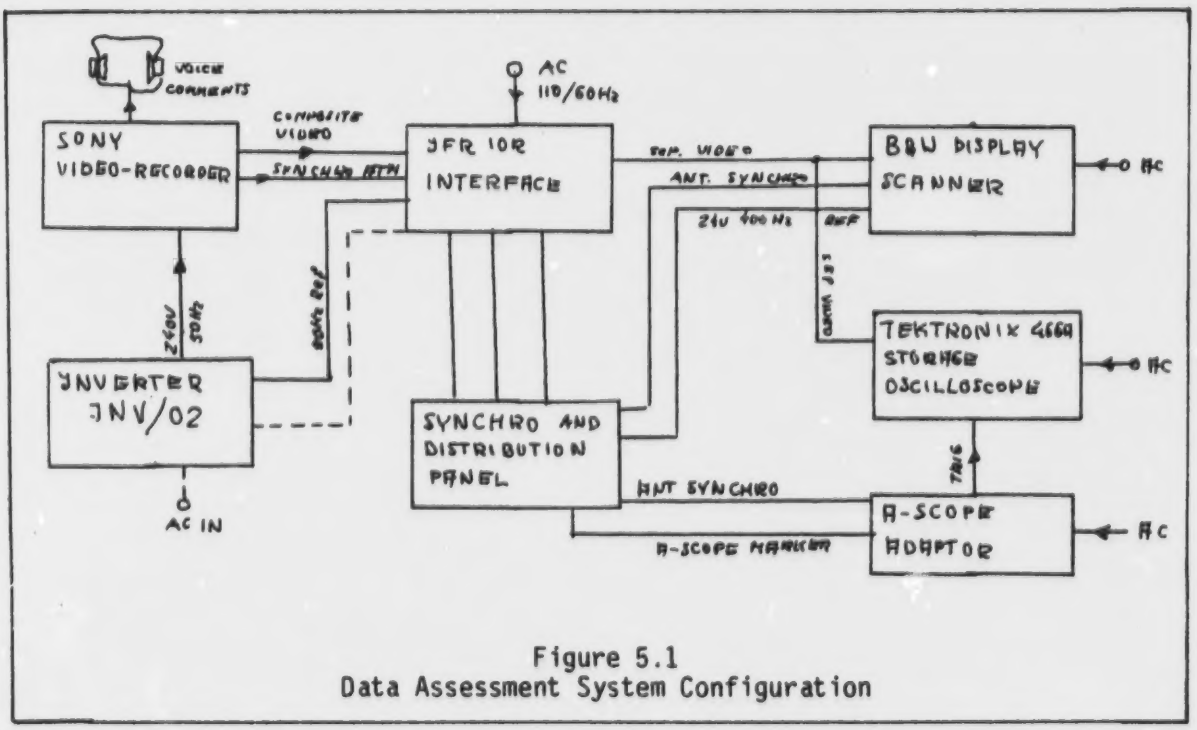


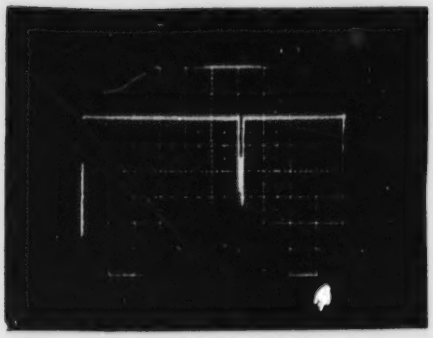
Figure 5.1
Data Assessment System Configuration

Before commencing the observation program, the system was provided with a suitable adaptation for a Sony type VTR 103 video recorder. The recorder worked in line and in a mode fully synchronous with a marine navigation radar system. For the purpose of the experiment the system was equipped with three types of antennas to enable the use of different polarization and heights. In order to obtain radar returns displayed as electrical pulses on a storage oscilloscope screen, an A-Scope adaptor was added which included a manually tuned digital bearing switch. As a result, in addition to a 360 degree field of observation on the B & W scanner, a selected target echo could be transferred in an analog pulse form to the Tektronix 466A storage oscilloscope screen and could be viewed simultaneously.

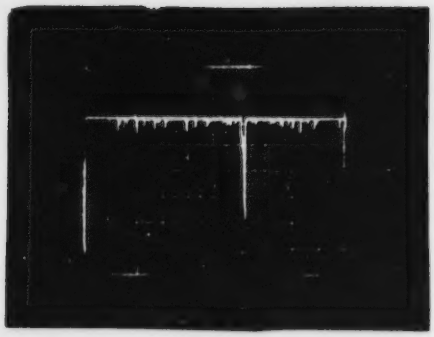
In order to select well correlated and stable targets it was necessary to review 72 events. These events were initially screened from a total of 391 described in the associated log books. This part of the project required approximately 120 hours of equipment operation.

This included tape winding, rewinding, noting comments recorded on the voice channel and determining bearings and ranges. During this time the Signal/Noise and Clutter ratio was measured (described later) from the storage oscilloscope. During subsequent evaluations of the same event on the same target, different noise levels accompanied the signal during the observation times, thus indicating that the results are non-repetitive. This indicated a very serious problem with data evaluation. If the results were non-repetitive there was little use in attempting to correlate radar performance with any environmental or physical conditions in effect at the time of recording. Therefore, more accurate measurements were made for one particular event, event number AG-06 sequence 1, combination 2, first scan. These measurements were made five minutes after switching on all equipment, again after one hour; after two and a one half hours and finally after 6 hours of continuous operation. The results are shown in the photographs number 1-4 for X-band (Fig. 5.2) and number 5-8 for S band (Fig. 5.3). The same observations were taken for other events on different tapes and the same deterioration of S/N occurred with respect to time. For the target selected in event AG-06, the difference of signal to noise ratio after 6 hours of operation is -8.19dB. This indicates a deterioration rate of approximately 1.37 dB/hr. The source of this destability was investigated. By switching on and off different components of the system and taking measurements the noise source could be isolated. The noise source turned out to be the video recorder and inverter which generated increasing amounts of noise as it heated up to operating temperatures. This effect was discovered at the beginning of the measurement stage of the project and as a result only a minor amount of work needed to be repeated. However, it did slow down the measurement program since the solution to the problem was to run the equipment in a cold state.

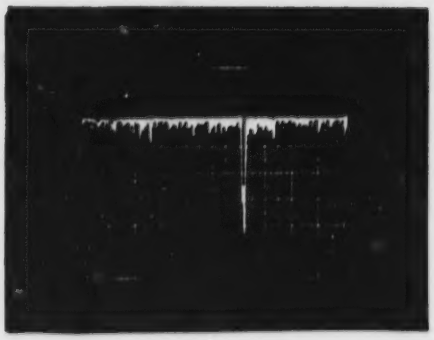
Event AG-06	Band X	Seq. 1	Comb. 2	Scan 1
Bearing 118.0	Range 8.8 nM	Tape 35	Counter 681	
Horiz. 20 μs/Div.	Vert. 0.5 V/Div.			



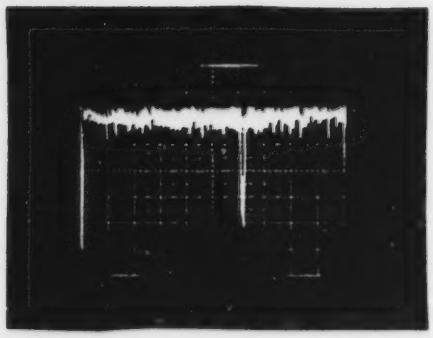
5 min S/N = 24.6 dB



1 hr. S/N = 20.5 dB



2.5 hrs. S/N = 19.73 dB

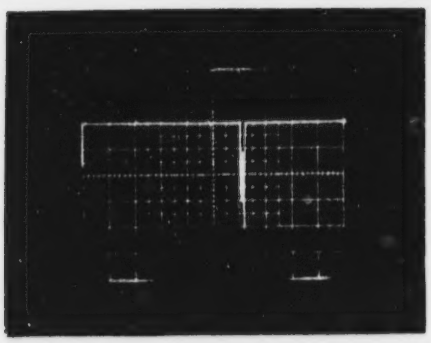


6 hrs. S/N = 18.8 dB

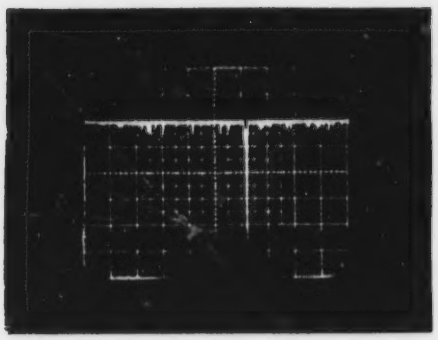
△ S/N = 5.8 db (S/N = 1.94)

FIGURE 5.2
SYSTEM NOISE INCREASE WITH TIME

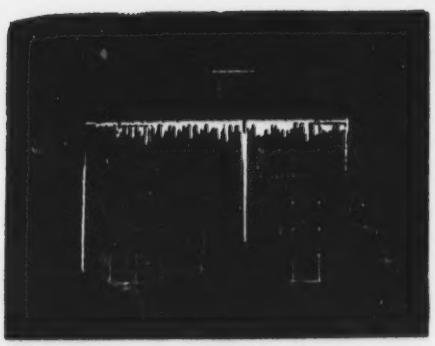
Event AG-06	Band S	Seq. 1	Comb. 2	Scan 1
Bearing 118.0	Range 9.8nM	Tape 36	Counter 681	
Horiz. 20 μs/Div	Vert. 0.5 V/Div			



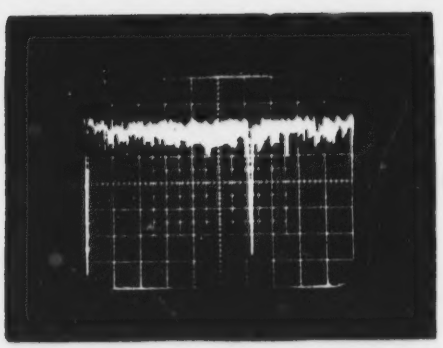
5 Min. S/N = 26.24 dB



1 Hr. S/N = 23 dB



2.5 Hrs. S/N = 20.3 dB



6 Hrs. S/N = 18.97 dB

△ S/N = 7.43 dB (S/N = 2.35)

FIGURE 5.3

SYSTEM NOISE INCREASE WITH TIME

Destability of the video recorder caused calibration problems with the interface block after installation by REMOTEC staff, and periodic recalibration of a few points inside the interface was necessary to obtain proper stability of the antenna rotation synchro pulse levels and sufficient space between the video pulses and the synchro gate. This suggested that the source of destability might also be located inside the interface block, however, a well calibrated interface retains its operating performance characteristics after several working cycles. Only fifteen percent of the tapes evaluated required a small readjustment using a potentiometer placed on the ATM module to ensure stable operation.

If calibration of the inverter was conducted while the video recorder was fully warmed up, then after cooling down the video recorder the targets were barely visible in the B & W display until the recorder had warmed up due to the very critical regulation range. In summation, it was necessary to calibrate the interface when the recorder was cold, and take measurements only when the equipment remained cool. This significantly increased the measurement cycle times.

During the data evaluation phase several small equipment problems arose. These problems were not insurmountable. For example, inverter INV/02 110 V/60Hz to 240 V/50Hz (supplying the video recorder) was connected to an AC line through a line to ground interference rejection filter. An IFR-103 interface was connected through this filter in parallel with the inverter. The maximum allowable AC current through the filter as determined from the factory label was 2.5A, but the idle current taken by a non loaded inverter during video recorder operation required 4.062A on the primary side. As a result of overcurrent, the filter burned out. Another filter connected to the spare interface was also burned out when checked by Viatec. Because of long delivery times for the proper 5A passing current filter, a 3.5A filter was installed for the interface only and connected from the AC voltage mains directly to the inverter (bypass filter). Checks were made to ensure that any interface noise did not disturb the video signals.

Another small problem occurred with the B & W scanner variable range marker. The marker indicates the dialed range in nautical miles. The sensing part linked in the tuning knob is equipped with an optocoupling pickup and a variable perforated wheel. This is very susceptible to dust. No cover is provided to protect this component and as a result requires regular cleaning of the optical pickup service.

The remainder of the system blocks in Figure 5.1 worked properly. During observations in the field it is not possible to exclude any technical problems especially with the experimental nature of this kind of work and as a result, it is a good idea to use a recalibration system. It is most important from a qualitative point of view, because not only are standard displays on a radar display important from a research point of view, they are also important for the navigation and safety of the ship. Additionally, switching operation modes will increase the possibility of malfunctioning. Therefore, a checking and reference mode was implemented by adding in the observation program in mode 2 one calibration combination. In addition, a special MODE-5 called "Simulated operation" was planned. However, no more than two events with recorded signals and comments were directed to this calibration operation. This problem was compounded with many factors responsible for variable performance such as sea state, precipitation and ship's rolling. Independently of the above, in some tapes a high level noise signal created by cross-coupling in the transmitting part of radar was partially recorded. This could be due to a malfunction in the TX/RX switch or the directional coupler. This part of the collected data is completely useless. It is assumed that periodic noise measurements during the cruise overcame these problems. Checking the output noise level withan oscilloscope or true RMS voltmeter (readout should be taken in absence of targets in order to avoid an integrating effect), was very difficult.

5.3 Data Evaluation

5.3.1 The Data Set

The radar observation data, collected by REMOTEC Applications Inc. staff, consists of 257 video tapes with a 60 min. recording time for each tape, half of which are X band recordings and half of which are S band recordings.

With regard to the tapes, 391 individual events of radar and visual observations are described in a total of 7 log books. Accompanying photographs (taken by a 35 mm camera with convertible lenses) were stored in envelopes.

The majority of the collected photos in envelopes (numbered in order by succession of events) are provided with useful annotations to correlate them with the tapes.

In order to obtain a variety of data the field program was conducted with cross-tabular lists for different environmental and physical conditions such as; different antenna polarization and heights, long and medium width of transmitting pulses and variable antenna rotation speeds. This was all completed sequentially using all possibilities which could be provided by the installed ship's radar equipment.

Displayed on a radar screen, the observation field was generally fixed at a range of up to 12 nautical miles, but on one sequence (No. 22 on mode 4S) a short range mode was provided with a 1.5 nM range performance. The above measurement methods demanded continuous switching of different modes of operating parameters and also a suitable ship's course for a selected target on the inbound and outbound mode.

5.3.2 Data Correlation

Once the technical problems with equipment in both phases (the field observation phase and evaluation of the video-tapes at Viatec) were rectified or accounted for, it was ascertained that there is no correlation between the radar and the visual observations in more than 80% of collected data.

The desired correlation could not be obtained as the target photographs for a given bearing often contained more than one ice target and in addition photograph information was found in some cases to disagree with the logbook information.

Only two events were found in which very accurate information correlating the target's proper radar bearing, with voice comments were documented. Unfortunately these selected events (CO-03 and BM-01) were not representative of all the larger selected targets recorded in mode 4S.

On a few events recorded in mode 4S no targets were found whatsoever. Sometimes there are different pictures on the X-band and the S-band type of radar. Targets visible by replaying the recorded S-band tape are not presented on X-band recorded tape and vice versa. More details about the collected data and initial classification problems were desribed in a section of a previous Viatec montly report entitled, "Data Quality Evaluation" and are presented here.

In conducting the first phase of the project, we chose to implement two main steps of research activity:

Step 1: Any and all such events were eliminated which were inaccurately recorded on tape, or documentation was not completed due to the following reasons:

a) - no targets at all, or targets are very far and very small (26.3%)*
b) - no accompanying visual observations (photographs) (25.6%)*
c) - no supporting descriptions in log books or additional documentation (8.3%)*
d) - high fog density, or poor visibility (8.4%)*
e) - incorrect equipment operation by ships crew (6.9%)*
f) - equipment malfunction, or weather problems such as: high sea state - which produce non effective observations at close range (6.2%)*

(%)* - is the percentage of total number (391) of the collected events.

As a result of this primary selection we concluded that 18.2% of the material was of satisfactory quality to conduct further analysis.

Step II: After carefully reviewing the remaining video tapes and accompanying visual observation photographs, elimination of those events defective due to the following reasons was undertaken:

a) - no accompanying visual observation (photographs were taken without focus adjustment) (22.5%)**
b) - no documentation at all, empty envelope (14%)**

c) - unacceptable correlation between data in the log book and that on video tapes, (for example, wrong bearing and range information in scans which consist of more than two targets) (9.9%)**
d) - video tape not corresponding to log description (9.9%)**
e) - target unsteady on reproduced event or shortage of scans (7%)**
f) - no records on tape or part of tape (5.6%)**
g) - ship geographic position questionable (5.6%)**

(%)** - is percent of the 71 primary selected events.

Of the 71 primary selected evented, 18 were adequately documented. Finally, all measurements and conclusions for further data analysis will be based on the 18 selected events which comprise 4.6% of the total number of collected events. Table 5.1 describes the 18 adequate targets and Table 5.2 describes the 6 best targets.

Once the well documented targets had been selected, there was several options available in order to make use of the data. At that point the results could be simply reported and no further action taken. An attempt could have been made to selectively digitize some of the data in order to assess the capability of performing this function with the equipment in hand. This idea was not taken any futher as it would have proven extremely expensive and time consuming. This activity is recommended for future consideration, as it will be required in order to conduct any digital signal processing and enhancement, and this maybe the area where the data may prove valuable as a unique data set.

The other major area of usefulness of the data is to attempt a preliminary analysis of the data as it now stands. This analysis would enable the data set to stand alone as a body of knowledge from which useful information can be derived with respect to optimum performance characteristics of various radar system combinations in various sea states and prevailing environmental conditions against variable targets. This preliminary analysis was within the scope of this project and was conducted. Evaluating the performance of the system could fulfill several purposes. First, it might support theoretical calculations of optimum radar performance against iceberg targets. Secondly, an analysis could be used to validate and support the analysis and conclusions presented by Remotec Applications Inc. in their final report, and finally, the basic calcuations would assist us in ensuring that the final selected targets were in fact useful. As a result, Viatec attempted to make some conclusions about radar performance against iceberg targets under variable environmental conditions.

The first step undertaken was to attempt to identify from Signal/Noise ratios alone the best radar parameters for iceberg detection, and compare them to the findings of the Remotec Report.

No.	Event	Mode:	Sequence/Cominbation	Log Book	Tape No.	Counter
1	AA-03	2	1/1-6, 2/2-5, 3/1-6, 4/2-5	1	7, 8	486-549
2	AB-10	2	1/1,2,5,6, 2/2-5, 3/2,5,6, 4/2-4	1	11,12	686-747
3	AD-10	2	1/1-6, 2/1-6, 3/1-6, 4/1-4	1	19,20	594-704
4	AE-14	2	1/1-6, 2/1-6, 3/1-6, 4/1-6	1	27,28	791-891
5	AG-06	2	1/1-6, 2/1-6, 3/1-6, 4/1-6	2	35,36	679-756
6	AG-07	4s	13/1-12, 14/1-12, 15/1-12, 17/1-15	2	35,36 37,38	756-855 000-150
7	AH-09	2	1/1-6, 2/1-6, 3/1-6, 4/1-6	2	41,42 43,44	837-894 000-065
8	AJ-04	2	1/1-6, 2/1-6, 3/1-5,	2,	49,50	403-584
9	AO-02 //03	2// 4M	1/1-6// 9/1-18, 10/1-18, 11/1-18	3	65,66	000-066 068-404
10	AK-09	2	1/1-6	3	55,56	503-535
11	AW-03	2	1/1-6, 2/1-6, 3/1-6	4	89,90	210-367
12	AS-01	2	1/1-6, 2/1-6, 3/1-6	4	83,84	617-739
13	BQ-01	4s	13/1-12, 14/1-12, 1/1-10, 17/1-18, 18/1-16, 14/6-12, 15/1-10, 13/1-12, 14/1-5, 15/11-12, 16/1-12	6	180,181 182,183	210-895 000-731
14	BO-02	4s	17/1-18, 18/1-18, 19/1-15, 18/7-14, 19/5-13, 20/15-18 13/1-12, 14/1-12, 15/1-12 16/1-4	6	168,169 170,171 172,173	497-870 000-871 000-472
15	BM-01	4s	22/1-27, 22/1-29, 22/1-28 13/1-12, 14/1-12, 15/1-12 16,1/12, 13/1-12, 14/1-12 13/1-12, 14/1-12, 15/1-12 16/1-12	6	146,147 148,149 150,151	285-902 000-891 000-862
16	CO-03	2	1/1-6, 2/1-6, 3/1-5	7	250,251	805-901
17	CH-04	4s	22/1-27, 13/1-12	7	238,239	000-633
18	BX-02	4s	17/1-18, 18/1-18, 19/1-18, 13/1-12	7	218,219 220,221	003-842 000-368

TABLE 5.1
THE 18 ADEQUATELY DOCUMENTED TARGETS

EVENT	TAPES	COUNTER	MODE	BEARING Degrees True	RANGE Nautical Miles	PHOTOS	DESCRIPTION
AA-03	X R-7 S R-8	486-491	2	343	2.55	B-32 24/25	large blocky med. titled
AB-10	X R-11 S R-12	686-747	2	261	2.40	B-63 10A	large blocky
AD-10	X R-19 S R-20	594-704	2	270	2.40	B-63 2, 8	large tabular
AH-09	X R-41 X R-43 S R-42 S R-44	837-894 000-065 837-894 000-065	2	270	2.54	B-172 30-35	very large iceberg
BM-01	X R-146 X R-148 S R-147 S R-149 X R-150 S R-151	285-902 000-891 285-902 000-891 000-862 000-862	4s	271	1.4	colour photo	dry dock
CO-03	X R-250	805-901	2	156	1.02	B-331 14-18	Very large blocky (very close to ship)

TABLE 5.2
THE BEST CORRELATED TARGETS

During this signal-to-noise ratio analysis an attempt was made to ensure that the combinations and sequences considered would allow for a comparison of the various radar parameters. A choice of sequences and combinations had to be made to vary antenna polarization, antenna height, and pulse width. A determination then had to be made in order to decide which parameter was responsible for the highest signal to noise ratio for all types of targets varying in size and range etc. Table 5.3 outlines the radar parameters utilized during the field trials.

The following measurements were carried out:

a) Signal/noise ratio of radar returns versus target range.

b) Signal/noise ratio of radar returns versus sea state.

c) Signal/noise ratio of radar returns versus target size.

d) The above measurements were then compared relatively between the X-band and the S-band type of radar.

From a systematic review of these measurements, it was concluded that it would be very difficult to form absolute conclusions pertaining to the optimum radar parameters for iceberg detection.

There are many reasons for making this statement and some of them are presented here. During mode 4S recorded events on video tapes were taken as the ship circumnavigated the target at an almost steady radius, but for our purposes continuous observation from the minimum safety range to 12 nM would yield more useful information when data was collected on both the inbound and the outbound mode. The majority of data for each event does not belong to one well documented target set supported by photos. This factor should be considered in the mode 4S of operations. It was decided to increase the quantity of measurement points for each target and to determine the mean value from a minimum of three points to more than twenty, in order to make a better determination of each particular signal to noise ratio. Large errors are present, but trends can be determined.

Considering all environmental conditions such as weather, which affects the ships movement and sea state and attempting to produce an intercorrelation between data it was estimated that the resolution provided by the system declined by 1 - 2 dB. Noise created by video-recorder,described earlier in section 6.1 is 1.27 dB/hrs. Therefore it is impossible to ignore previously recorded data containing such significant errors. In spite of all the inherent error it was decided to group selected targets by possible equal size, or equal range depending on the necessity to make objective conclusions and by systematically altering other parameters and making conclusions as best as possible.

FREQUENCY BAND	TRANSMIT POWER (kw)	PULSE LENGTH (μsec) / PULSE REPETITION FREQUENCY (Hz)			RANGE RESOLUTION (m)			ANTENNA ROTATION SPEED (rpm)	ANTENNA DESIGNATION	HEIGHT (m)	POLARIZATION *	ANTENNA GAIN (dB)	ANTENNA BEAMWIDTH (degrees)		AZIMUTH RESOLUTION AT 1Km (m)	LOSSES (dB)+
		LP	MP	SP	LP	MP	SP						Vertical	Azimuth		
X	20	0.9 / 847	0.22 / 1695	0.04 / 3390	135	33	6	6-24	HA-1	17	HH / CP	HH-31 CP-28	20^{o}	0.8^{o}	14	9
									HA-3	12.5	HH	30	20^{o}	1.2^{o}	21	7.4
S	30	0.9 / 847	0.15 / 1695	0.075 / 3390	135	22.5	11.25	30	HA-2**	15	HH	27	25^{o}	2^{o}	35	7.2

* HH - Horizontal Polarization
CP - Circular Polarization

+ These include system losses and a theoretical scanning loss

** For the S band radar only one antenna height HA-2 was used.

TABLE 5.3 - RADAR SYSTEM PARAMETERS

5.4 Results

The results are based on an attempt to evaluate radar performance based on the parameters used at the time of measurement with a comparison to the Signal/Noise ratios achieved. Measurements were made of signal to noise ratio - as voltage ratio in dB calculations; not power ratio as usually used in radar technique for determining cross-section:

$$s/n \quad (dB) = 20 \log \frac{\text{signal value}}{\text{noise value}} \begin{matrix} (\text{peak}) \\ (\text{avg.}) \end{matrix}$$

It is understood that this kind of determination is not completely objective. It is fairly easy to determine accurately the amplitude value of the reflected pulses, by using a well calibrated oscilloscope vertical amplifier. At the same time, however, determination of noise value is very difficult. The average noise level was determined visually from parts of the signal where no radar targets are present.

The accuracy of the above method is not very good (more than 15% error) but without additional pre-processing it was not possible to use a standard laboratory TRUE-RMS voltmeter. To use one, it would be necessary to separate that part of the signal which consists only of noise.

It was observed that reproduced signals from video tapes are not completely free from some DC offset, however this is a normal magnetic recording-reproducing effect. This effect is eliminated partially by readjusting the amplitude base level on the oscilloscope, however, this small shifting of signals produces less than five percent of the errors in determining the signal/noise ratio.

Therefore, we were not concerned about the absolute value of the signals, but rather evaluations and subjective selection between each particular parameter. Using standard equations to determine the radar cross section cannot be done because all signals are recorded from formerly fixed components that cannot be subtracted or separately analyzed. In addition, differences between the X and S band radar systems made comparison difficult. Some of the problems encountered are listed here.

a) different power transmitted by each system.
b) long-term destability of system.
c) inequality of the receiver characteristic.
d) possibility of recording events (or part of it) in noise generated by recorder.
e) subjective determination of noise average value during analysis time in Viatec.
f) Video-tape DC offset
g) A-Scope resolution error (significant value on target size determination.

The results are displayed on the following graphs and are significant from a relative point of view, but absolute values on vertical dB axis contain significant errors from one or few of the sources of error described above.

5.4.1 The best parameters of radar system:

This calculation was made as a first measurement step, to conclude what kind of radar (X-band or S-band) will give the strongest signal at the receiver output in regard to a particular combination of antenna parameters and width of pulses.

Three main events were selected for this analysis; they are:

Event No AG-08 on targets grouped in range between 1 and 2 nM
Event No AH-09 on targets grouped in range between 4 and 4.5 nM
Event No AG-06 on targets grouped in range between 10 and 12 nM.

The targets were grouped in the above three ranges in order to eliminate range as a factor in S/N calculations. Fig. 5.4 and Fig. 5.5 titled "Signal/Noise ratio versus antenna polarization" display horizontal segments representative of the mean value of the data points for X and S band radar.

The three above events are supported by measurements ascribed to the following selected targets:

For range 1-2 nM from events: AB-10, CO-03, AE-14, BX-02, AW-03, BO-02

For range 4-5 nM from events: AA-03, AO-03, AK-09, AS-01, BQ-01, BO-02

For range 10-12 nM from events: BQ-01, AJ-04, BM-01

For event No. AH-09 the measured S/N ratio was attributed to the same target on each seq. and combinations Mode 2 Seq. 1 - 4, and combinations 1 - 6. Photos were taken by synchronizing the A-Scope adaptor to the proper bearing. Selected results are displayed in Fig. 5.6 to 5.9 for the X-band radar, and Fig. 5.10 to 5.13 for the S-band radar. Table 5.4 summarizes the parameters in effect for the various sequences and combinations.

Conclusions:

a/ Generally the S-band radar produces a stronger output signal to noise ratio than the X-band radar, basically for all combinations of antennas and pulse widths.

b/ The X-band radar is subject to less signal attenuation with distance in steady weather if no precipitation is present. This can be determined from measuring the slope of S/N curves in Fig. 5.14, where it can be seen, that, within the limitations or inherent error, the slope of the curve for X band radar returns is less than that for the S band radar returns.

c/ The best combination of parameters is:
- Long transmitting pulse - 0.9 us and 847 Hz repetition frequency. (LP).
- Horizontal polarization of antenna (HH)
- 12.5 m height of antenna above sea level (HA-3) for X band, and 15m height of antenna above sea level (HA-2) for S band.

d/ Signals from both types of radar are more dependent upon pulse width than the antenna height.

5.4.2 Discussion and Comparison to the Petro Canada/TDC Final Report

This report prepared by Remotec Applications for Petro Canada and TDC entitled; "Field Evaluation of Sensors for Development of a Ship Mounted Ice Hazard Dectection System", was studied, and based on the conclusions of the Viatec data evaluation, the following conclusions can be drawn from the Remotec report.

Conclusions:

a/ Generally, the aspects of the report dealing with radar signal returns is properly done, if both types of radar receivers have the same characteristic curves. It is noteworthy to use caution on interpreting the graph in Fig. 2 "Receiver response curve, as measrued in the lab using signal generators" (supplement to Petro Canada. final report)[7]. This curve was considered valid for two different radar receivers, and in Viatec's opinion is real only if long-term stability is held, and characteristics remained steady during the observation time in the field. This is important, if we take into consideration the long periods of observation time (external data collection consisted of almost 2 months in the offshore environment). Recorded signal differences of less than 3 dB (in short and long ranges) are insignificant over this time frame if long term stability is not present.

It is important too, that power transmitted by the S-band radar transmitter is 30 kW, but the transmitter of the X-band system has only 20 kW power in pulse. (see page 27, Petro Canada report).

b/ The Petro Canada report stated that the physical properties of microwave frequencies explained longer detection horizons for the X-band radar (different clutter circle) rather than the 2.5m difference in antenna height, however, the higher placed antenna (max differences between antenna heights was 5m) also increased detection ranges and signal strengths.

With respect to graphs No. 4 for X and S-band, on range 10-12 nM, it is concluded that the dotted lines representing signal attenuations (disregarding the values between each ranges) are declining faster on the S-band type of radar. This effect is explained by the different beam widths of the antennas. A 2 deg. beamwidth of the S-band antenna in longer ranges is collecting more clutter and noise than on the X-band antenna with a 1.2 deg. beamwidth on the same range. If we assume the above, for purposes of ice detection, a narrower beamwidth and higher placed antenna would be recommended. Very slowly moving targets detected at longer distances, say at medium ranges of 4-5 nM on the graph, are poorly compensated by the characteristic of the receivers, and in Viatec's opinion, these characteristics are not the same and this factor is very important for comparing the two types of radar.

c/ It is estimated that the best polarization of the antenna is horizontal. Horizontal polarization produces stronger radar cross-section signals than circular polarization. Our results of measurements made during this study do not correspond to the results shown in the Petro Canada report graphs.

To summarize the above, the best combinations of parameters - LP HH HA3, producing the strongest output are presented in the following sequences.

MODE 2:

sequence	1	2	3	4	24 RPM of antenna rotation
combination	3	6	5	2	

MODE 4M:

sequence	9	10	11	12	
combination	9	7	4	6	24 RPM of antenna rotation
combination	10	12	15	13	16 RPM of antenna rotation

MODE 4S:

	sequence	13	14	15	16	17	18	19	20	21	22
24RPM	combination	6	4	1	3	3	1	4	6	1	1
20RPM	combination	7	9	12	10	10	12	9	7		18
16RPM	combination					15	13	16	18	13	19

For each radar, the resultant S/N ratio should be the same if other factors are steady (range and weather) for each target. All of the following conclusions are based on the measurement of S/N ratios for the combination of these parameters (LP-HH-HA3) only.

Figure 5.4 and 5.5 compares the Signal/Noise versus antenna polarization. It can be seen that in most cases horizontal polarization produces larger Signal/ Noise ratios.

SEARCH MODE # 2

RANGE 12 nM ANT: 24 RPM S BAND** AND X BAND 5 VIDEO SCANS

COMBIN.	SEQUENCE 1			SEQUENCE 2			SEQUENCE 3			SEQUENCE 4		
	Pulse	Polar	Height	Pulse	Polar	Height	Pulse	Polar	Height	Pulse	Polar	Height
1	LP	CP	HA1	MP	HH	HA3	MP	CP	HA1	LP	HH	HA3
2	LP	HH	HA1	MP	HH	HA1	MP	HH	HA1	LP	HH	HA1
3	LP	HH	HA3	MP	CP	HA1	MP	HH	HA3	LP	CP	HA1
4	MP	HH	HA3	LP	CP	HA1	LP	HH	HA3	MP	CP	HA1
5	MP	HH	HA1	LP	HH	HA1	LP	HH	HA1	MP	HH	HA1
6	MP	CP	HA1	LP	HH	HA3	LP	CP	HA1	MP	HH	HA3
A	LP	HH/CP	HA1	LP	HH/CP	HA1	LP	HH/CP	HA1	LP	HH/CP	HA1

LP = Long Pulse
MP = Medium Pulse

CP = Circular Polarization
HH = Horizontal Polarization
HA = Height of Antenna

** For S Band only one height and polarization of antenna was used HH and HA-2 (15m)

TABLE 5.4
SEARCH MODE PARAMETERS

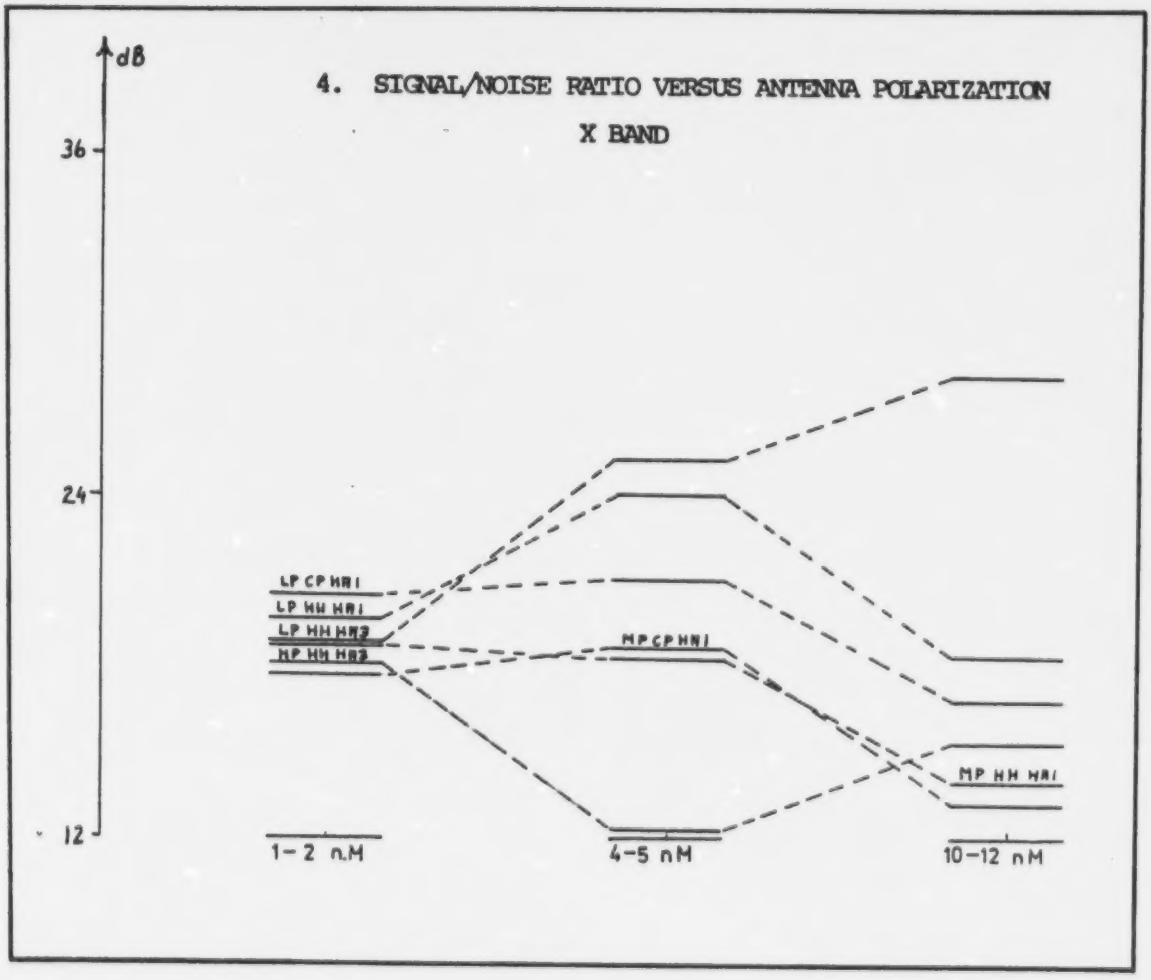

4. SIGNAL/NOISE RATIO VERSUS ANTENNA POLARIZATION
X BAND
dB
36
24
12
LP CP HA1
LP HH HA1
LP HH HA3
MP HH HA3
MP CP HA1
MP HH HA1
1-2 nM
4-5 nM
10-12 nM

FIGURE 5.4

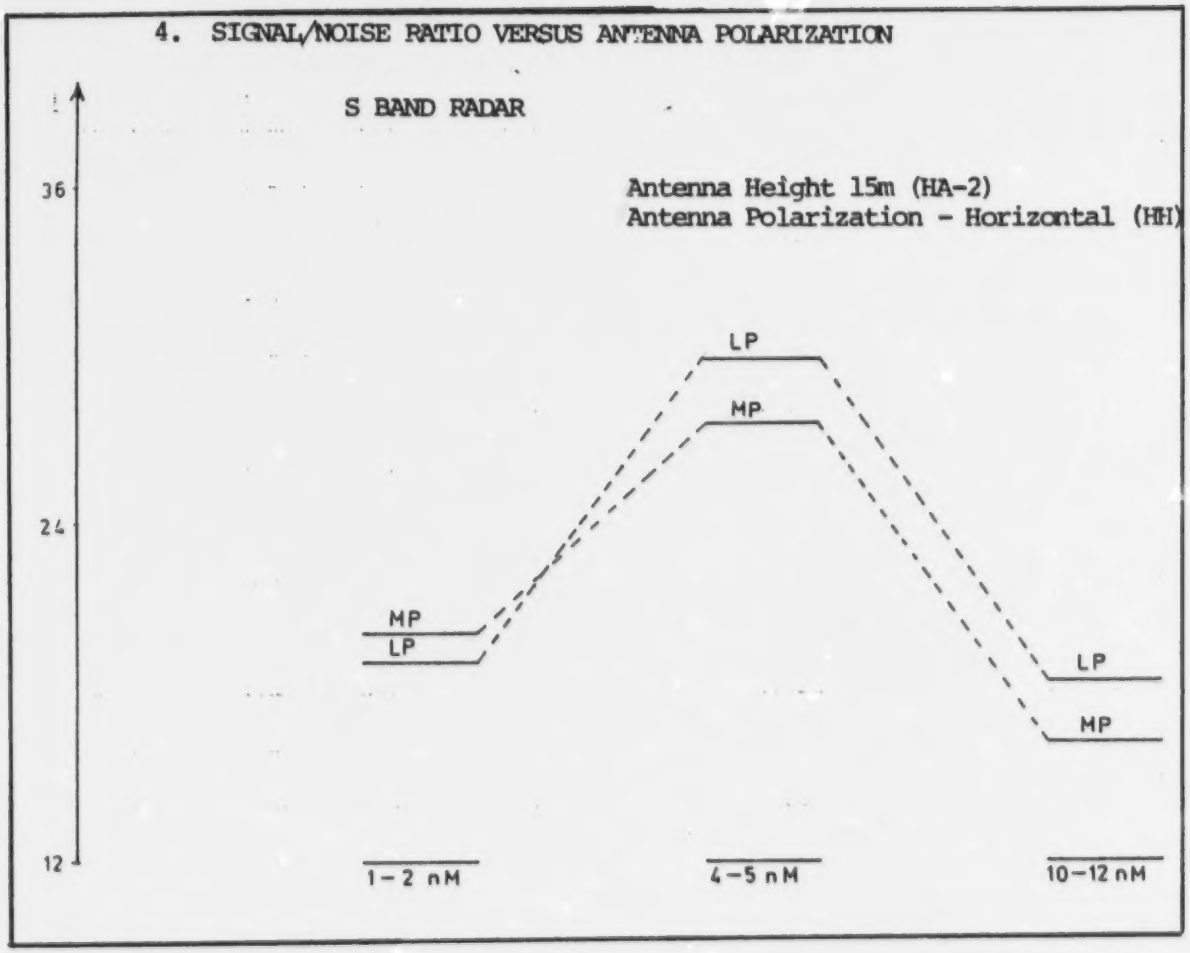
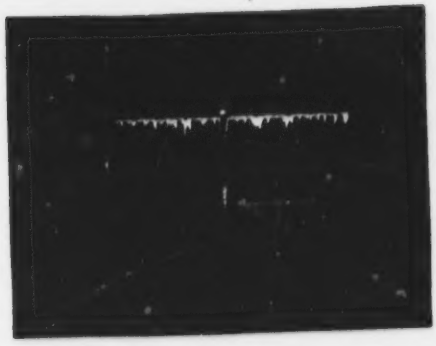

4. SIGNAL/NOISE RATIO VERSUS ANTENNA POLARIZATION
S BAND RADAR
Antenna Height 15m (HA-2)
Antenna Polarization - Horizontal (HH)
36
24
12
LP
MP
MP
LP
LP
MP
1-2 nM
4-5 nM
10-12 nM

FIGURE 5.5

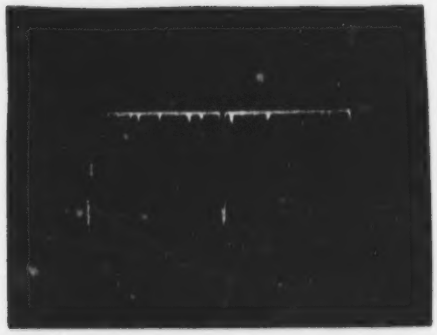
AH-09 X BAND Tape 41 Counter 839-851

Horiz. 10 μs/Div Range 4.21 nM

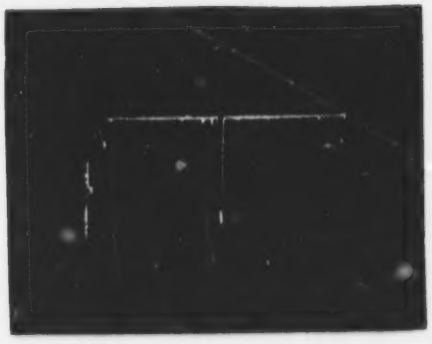
Vert. 0.5 v/Div.



Seq. 1 Comb. 1 23.22 dB

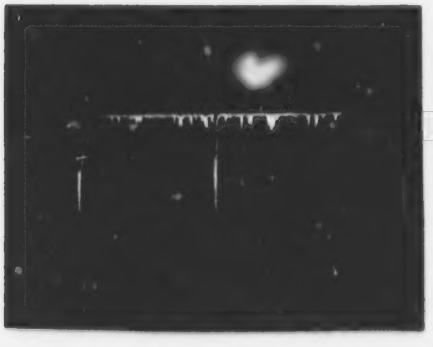


Seq. 1 Comb. 1 33 dB

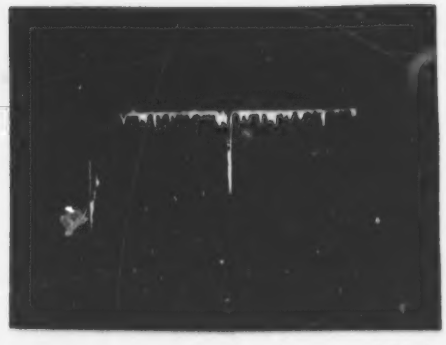


Seq. 1 Comb. 3 42 dB

Seq. 1 Comb. 4 21.6 dB



Seq. 1 Comb. 5 21.4 dB



Seq. 1 Comb. 6 18.4 dB

FIGURE 5.6

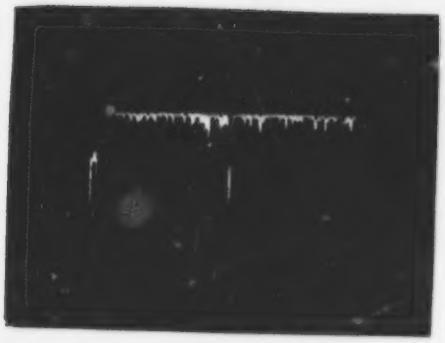
A SCOPE PHOTOS EVENT AH 09

AH-09 X Band Tape 41 Counter 853-870

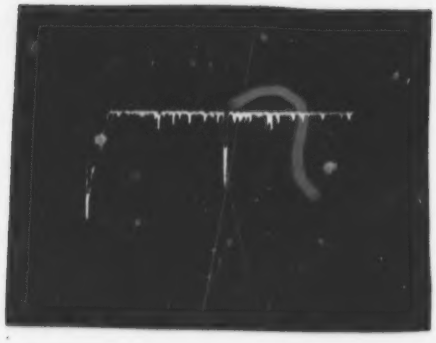
Horiz. 10 μs/Div Range 4.2 nM

Vert. 0.5 v/Div

Seq. 2 Comb. 1 19.1 dB

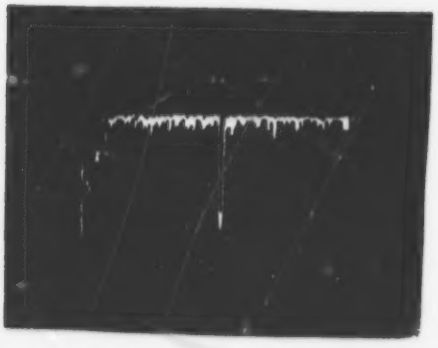


Seq. 2 Comb. 2 19.5 dB

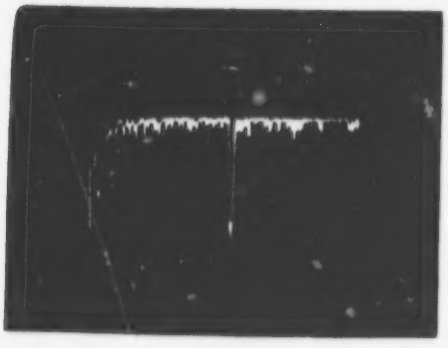


Seq. 2 Comb. 3 19.8 dB

Seq. 2 Comb. 4 20.8 dB



Seq. 2 Comb. 5 21.3 dB



Seq. 2 Comb. 6 23.5 dB

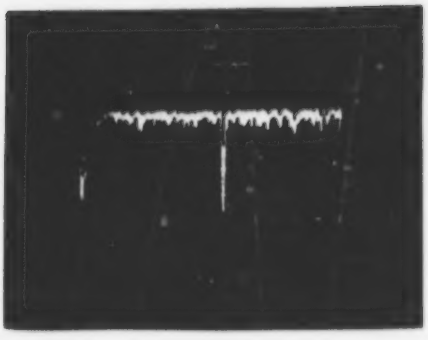
FIGURE 5.7

A SCOPE PHOTOS EVENT AH 09

AH-09 X Band Tape 41 Counter 894-891

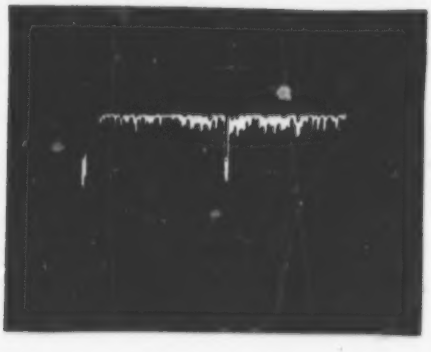
Horiz. 10 μs/Div. Range 4.38 nM

Vert. 0.5 v/Div.

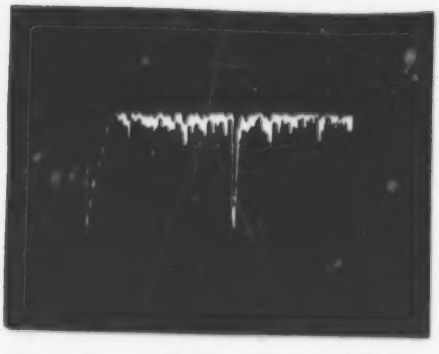


Seq. 3 Comb. 1 19.9 dB

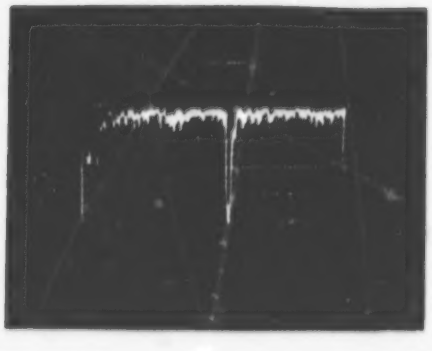
Seq. 3 Comb. 2 17.2 dB



Seq. 3 Comb. 3 15.4 dB



Seq. 3 Comb. 4 15.5 dB



Seq. 3 Comb. 5 21.5 dB

Seq. 3 Comb. 6 19.8 dB

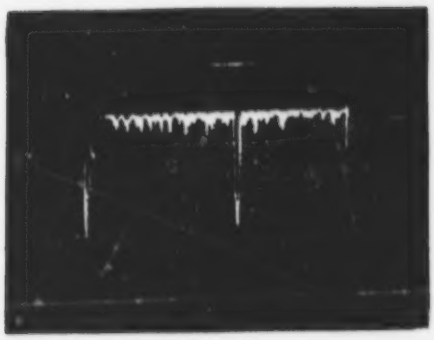
FIGURE 5.8

A SCOPE PHOTOS EVENT AH 09

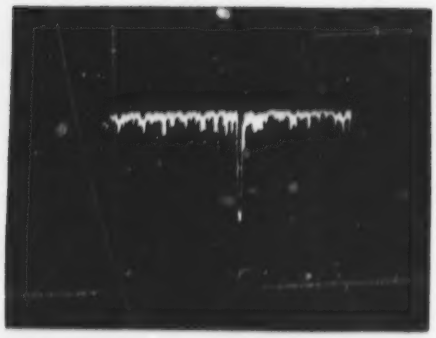
AH-09 X Band Tape 43 Counter 002-053

Horiz. 10 μs/Div . Range 4.36 nM

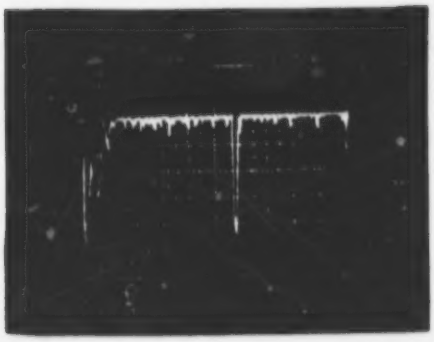
Vert. 0.5 v/Div.



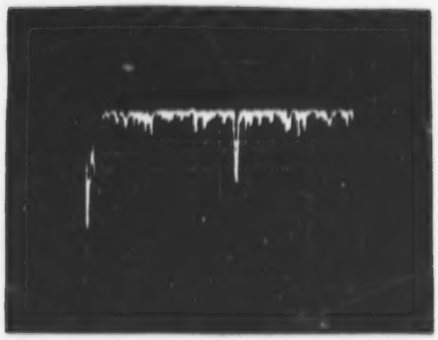
Seq. 4 Comb. 1 22.2 dB



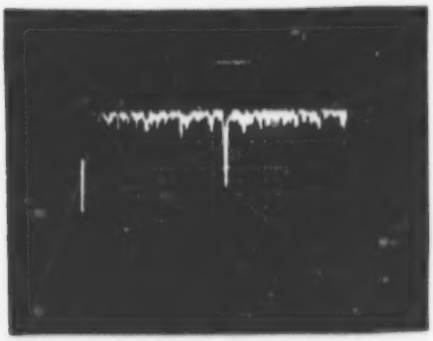
Seq. 4 Comb. 2 20.5 dB



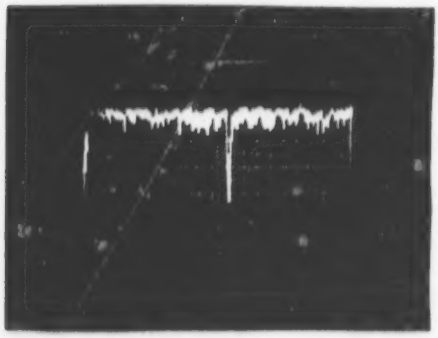
Seq. 4 Comb. 3 25.5 dB



Seq. 4 Comb. 4 16.8 dB



Seq. 4 Comb. 5 15.2 dB



Seq. 4 Comb. 6 17 dB

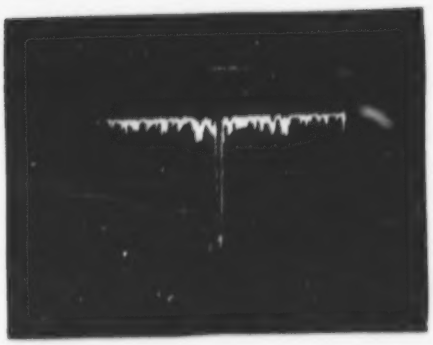
FIGURE 5.9

A SCOPE PHOTOS EVENT AH 09

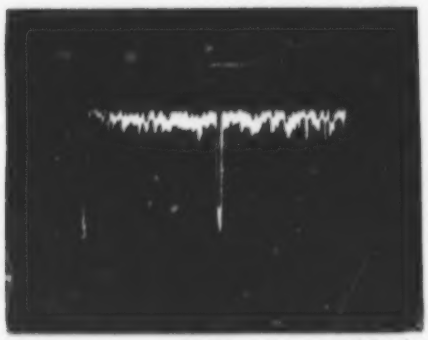
AH-09 S BAND Tape 42 Counter 839-851

Horiz. 10 μs/Div. Range 4.16 nM

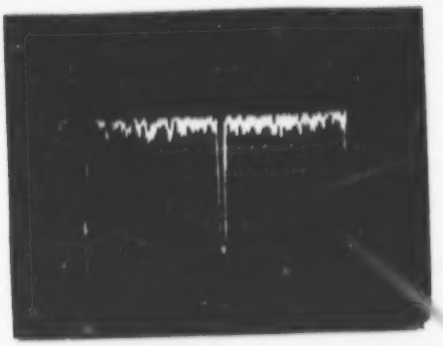
Vert. 0.5 v/Div.



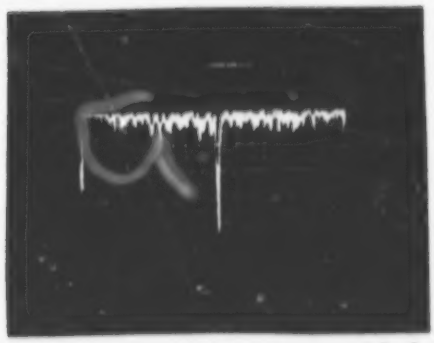
Seq. 1 Comb. 1 23.5 dB



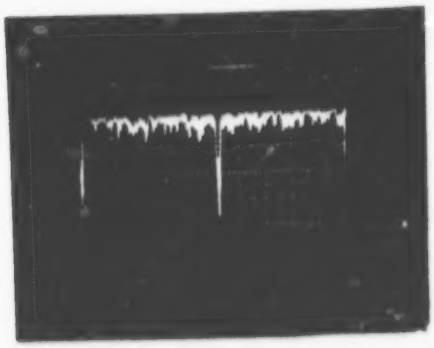
Seq. 1 Comb. 2 19.6 dB



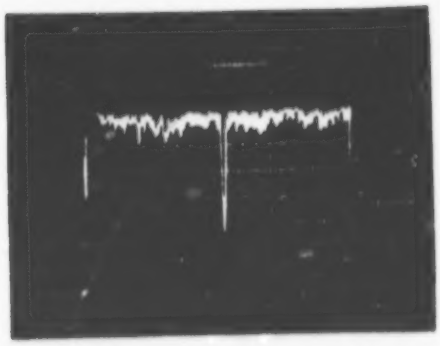
Seq. 1 Comb. 3 20.4 dB



Seq. 1 Comb. 4 13.5 dB



Seq. 1 Comb. 5 19.5 dB



Seq. 1 Comb. 6 19.0 dB

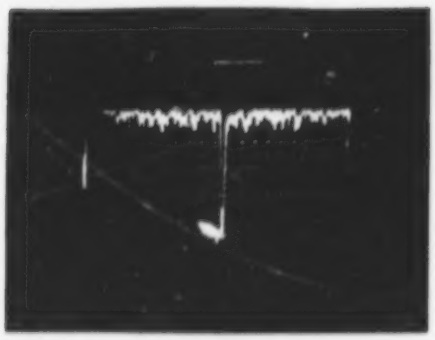
FIGURE 5.10

A SCOPE PHOTOS EVENT AH 09

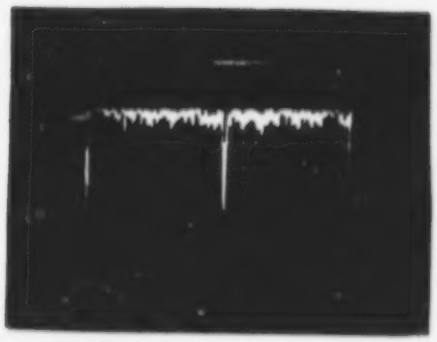
AH-09 S BAND TAPE 42 COUNTER 853-870

Horiz. 10 μs/Div.

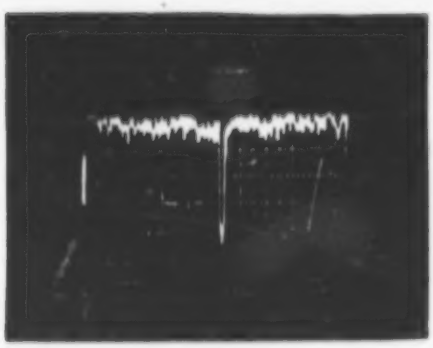
Vert. 0.5 v/Div.



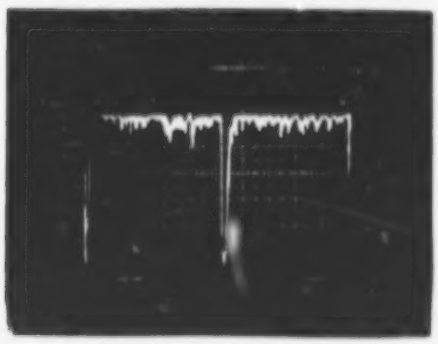
Seq. 2 Comb. 1 19.8 dB



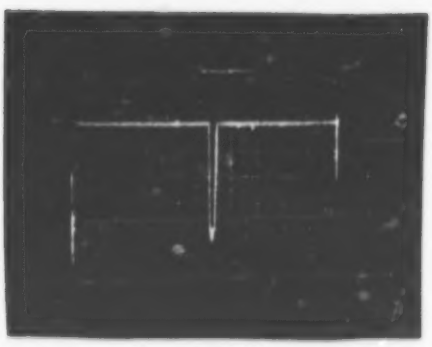
Seq. 2 Comb. 2 17.3 dB



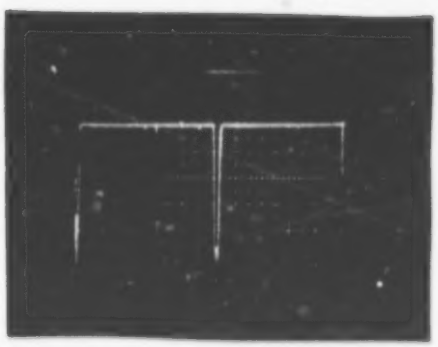
Seq. 2 Comb. 3 19.2 dB



Seq. 2 Comb. 4 21 dB



Seq. 2 Comb. 5 44 dB



Seq. 2 Comb. 6 48.5 dB

FIGURE 5.11

A SCOPE PHOTOS EVENT AH 09

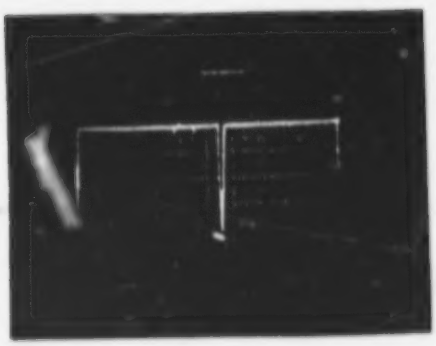
AH-09 S BAND TAPE 42 COUNTER 874-891

Horiz. 10 μs/Div.

Vert. 0.5 V /Div.

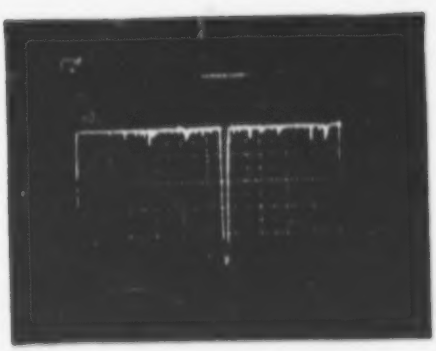
Seq. 3 Comb. 1 47 dB

Seq. 3 Comb. 2 46 dB

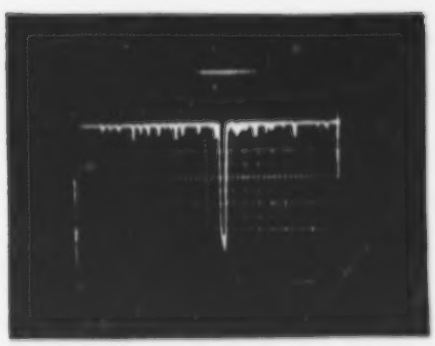


Seq. 3 Comb. 3 49 dB

Seq. 3 Comb. 4 47.6 dB



Seq. 3 Comb. 5 32 dB



Seq. 3 Comb. 6 27 dB

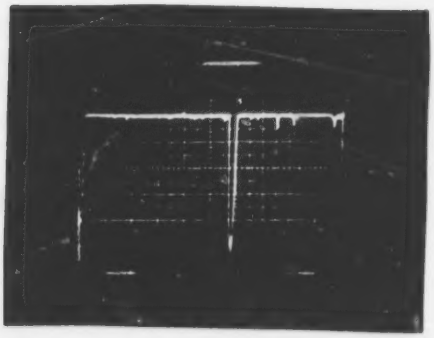
FIGURE 5.12

A SCOPE PHOTOS EVENT AH 09

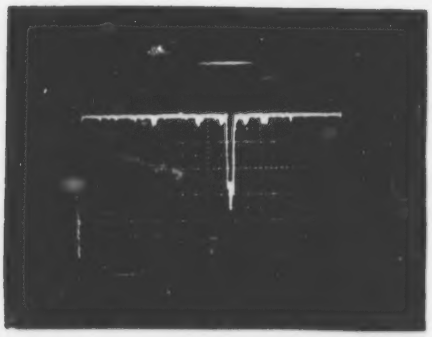
AH-09 S BAND TAPE 44 COUNTER 002-053

Horiz. 10 μs/Div.

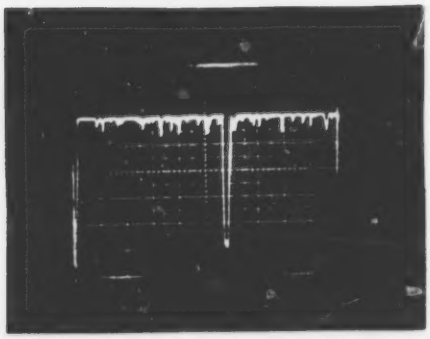
Vert. 0.5 v/Div.



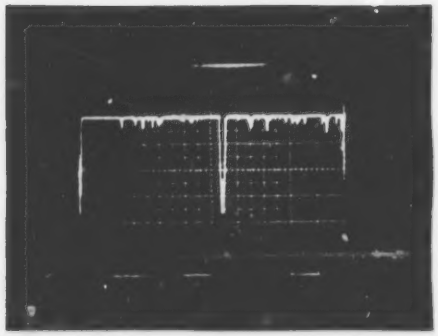
Seq. 4 Comb. 1 28.6 dB



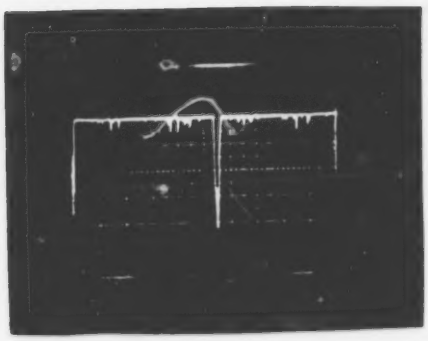
Seq. 4 Comb. 2 21 dB



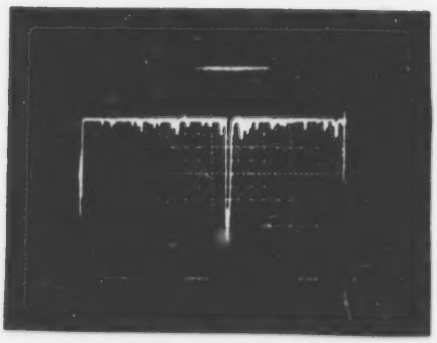
Seq. 4 Comb. 3 24 dB



SEq. 4 Comb. 4 23.3 dB



Seq. 4 Comb. 5 27.8 dB



Seq. 4 Comb. 6 23 dB

FIGURE 5.13

A SCOPE PHOTOS EVENT AH 09

TABLE 5.5

SIGNAL/NOISE versus Antenna Polarization

		S/N (dB)			
		1-2NM	4-5NM	10-12NM	
LP CP HA1 (X BAND)					
Seq.	Combin.				
1	1	19.3	23.22	15.8	
2	4	18.4	20.80	18.3	
3	6	18.9	19.80	16.6	mean = 19.46
4	3	25.3	20.5	16.6	
		$\bar{x}$ 20.48	$\bar{x}$ 21.08	$\bar{x}$ 16.83	
LP HH HA1 (X BAND)					
Seq.	Combin.				
1	2	19.8	33.0	18.5	
2	5	18.1	21.30	18.2	
3	5	18.74	21.5	18.5	mean = 20.77
4	2	22.4	20.5	18.7	
		$\bar{x}$ 19.76	$\bar{x}$ 24.08	$\bar{x}$ 18.48	
LP HH HA3 (X BAND)					
Seq.	Combin.				
1	3	21.2	42.6	18.6	
2	6	19.3	23.5	18.2	
3	4	15.0	15.5	47.6	mean = 24.33
4	1	20.3	22.2	28.6	
		$\bar{x}$ 18.95	$\bar{x}$ 25.8	$\bar{x}$ 28.25	
MP CP HA1 (X BAND)					
Seq.	Combin.				
1	6	19.6	18.4	12.9	
2	3	17.25	19.80	12.5	
3	1	15.5	19.9	13.3	mean = 16.53
4	4	18.41	16.8	14.0	
		$\bar{x}$ 17.69	$\bar{x}$ 18.73	$\bar{x}$ 13.18	

MP HH HA1 (X BAND)

Seq.	Combin.	S/N (dB) 1-2NM	4-5NM	10-12NM
1	5	18.06	21.4	16.12
2	2	21.0	19.5	15.2
3	2	17.7	17.2	11.4
4	5	18.7	15.2	12.9
		$\bar{x}$ 18.87	$\bar{x}$ 18.33	$\bar{x}$ 13.19

mean = 17.03

MP HH HA3 (X BAND)

Seq.	Combin.			
1	4	16.7	21.6	16.12
2	1	18.1	19.10	15.7
3	3	15.0	15.4	14.6
4	6	22.4	17.0	14.6
		$\bar{x}$ 18.05	$\bar{x}$ 18.27	$\bar{x}$ 15.26

mean = 17.19

LP HH HA2 (S BAND)

Seq.	Combin.	S/N (dB) 1-2 NM	4-5NM	10-12NM
1	1	21.4	23.5	14.0
1	2	21.8	19.6	19.3
1	3	20.4	20.4	18.4
2	4	23.8	21.0	20.0
2	5	20.0	44.0	18.2
2	6	20.0	48.5	19.3
3	4	21.0	47.6	18.0
3	5	19.6	32.0	18.1
3	6	20.0	27.0	17.5
4	1	23.5	28.6	23.8
4	2	26.0	21.0	28.0
4	3	20.3	23.0	20.7
		$\bar{x}$ 21.48	$\bar{x}$ 29.77	$\bar{x}$ 17.95
1	1	19.6		
1	2	17.6		
1	3	13.2		
		$\bar{x}$ 16.78		

MP HH HA2 (S BAND)

Seq.	Combin.	S/N (dB)		
		1-2NM	4-5NM	10-12NM
1	4	27.5	19.6	17.4
1	5	26.8	19.5	17.4
1	6	26.0	19.0	16.0
2	1	23.5	19.8	17.2
2	2	23.5	17.3	18.0
2	3	21.4	19.2	16.5
3	1	19.3	47.0	13.5
3	2	19.6	46.0	16.3
3	3	19.3	49.0	15.5
4	4	18.4	23.3	24.0
4	5	18.4	27.8	26.0
4	6	20.4	23.0	20.4
		$\bar{x}$ 21.76	$\bar{x}$ 27.5	$\bar{x}$ 18.18

X Band Summary

Pulse	Polarization	Height	X BAND MEAN
LP	HH	HA3	24.33 dB
LP	HH	HA1	20.77 dB
LP	CP	HA1	19.46 dB
MP	HH	HA3	17.19 dB
MP	HH	HA3	17.03 dB
MP	CP	HA1	16.53 dB

			X BAND		
			1-2nM	4-5nM	10-12nM
LP	HH	HA3	18.95	25.8	28.25
LP	HH	HA1	19.76	24.08	18.48
LP	CP	HA1	20.48	21.08	16.83
MH	HH	HA3	18.05	12.28	15.26
MP	HH	HA1	18.87	18.33	13.9
MP	CP	HA1	17.69	18.73	13.18

S Band Summary

	S/N (dB)		
	1-2NM	4-5NM	10-12NM
LP	19.1	29.8	18.4
MP	20.1	27.5	16.2

5.4.3 Signal/Noise Ratio Versus Target Range

In order to evaluate this comparison, target range vs. signal/noise ratio, Viatec selected two events (BQ-01 and BO-02), and located the necessary targets on inbound and outbound measurement for target ranges of a small domed iceberg between 2.5 nM up to 15 nM. As discussed earlier the combination LP HH HA-3 was used for preparation of the graph No.1. The upper continuous line is an interpolated mean value of data points for S-band radar, and the lower line belongs to the X-band radar data points.

Other conditions such as weather, sea state, and precipitation are steady during this event.

According to the time based graph, the radar signal attenuation is determined to be :

0.66 dB per nautical mile for S-band radar.
0.58 dB per nautical mile for X-band radar.

5.4.3.1 Conclusion

Generally sea clutter level is responsible for signal/noise and clutter ratio. Destability of the ship's radar platform caused by the pitching and rolling movement is a source of clutter which is detected by the radar antenna as noise clutter. On steady seas the clutter collection effect is directly proportional to range.

5.4.3.2 Discussion and Comparisons

In the Petro Canada final report (page 41-44) the above problem is described by a series of tables. One table shows the maximum detection range versus antenna parameters, and on another seperate table, the average clutter levels are correlated to each particular sea state. However,this comparison is presented in a much more accurate fashion than is possible to depict since the detection levels (or minimum signal/noise ratio) that were used as a reference are not to be found anywhere.

In Fig. 5.14 and 5.15, events BQ-02 and BQ-01 are depicted. The signal/noise ratio was measured in sea state 4, which was the most severe environmental conditions considered. The sea states for the various events are illustrated in Table 5.6. In Viatec's opinion, it is not possible to objectively perform a correlation between sea state and clutter levels.

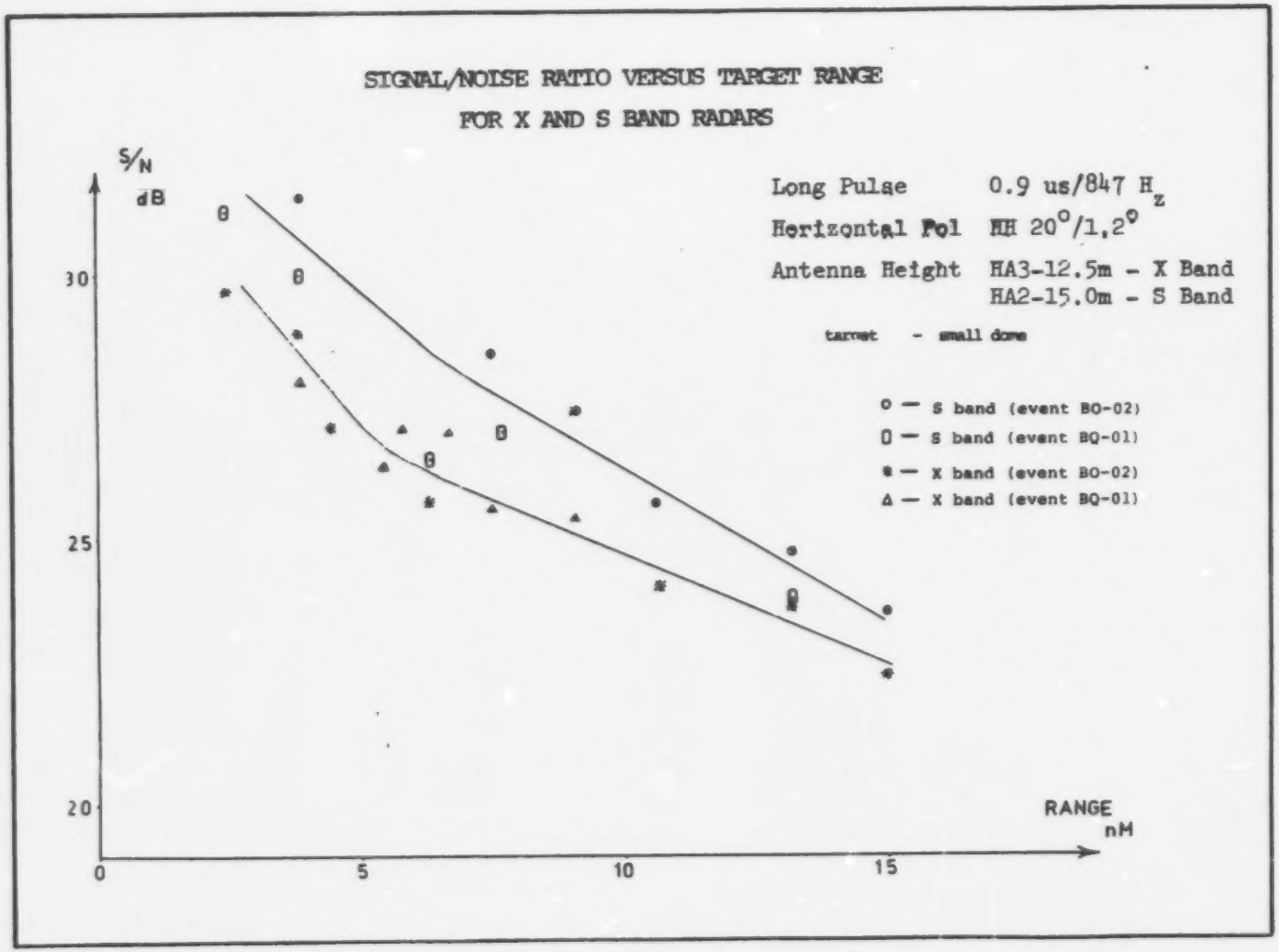

SIGNAL/NOISE RATIO VERSUS TARGET RANGE
FOR X AND S BAND RADARS
S/N
dB
30
25
20
0
5
10
15
RANGE
nM
Long Pulse 0.9 us/847 Hz
Horizontal Pol HH 20°/1,2°
Antenna Height HA3-12.5m - X Band
HA2-15.0m - S Band
target - small dome
o — S band (event BO-02)
□ — S band (event BQ-01)
* — X band (event BO-02)
Δ — X band (event BQ-01)

FIGURE 5.14

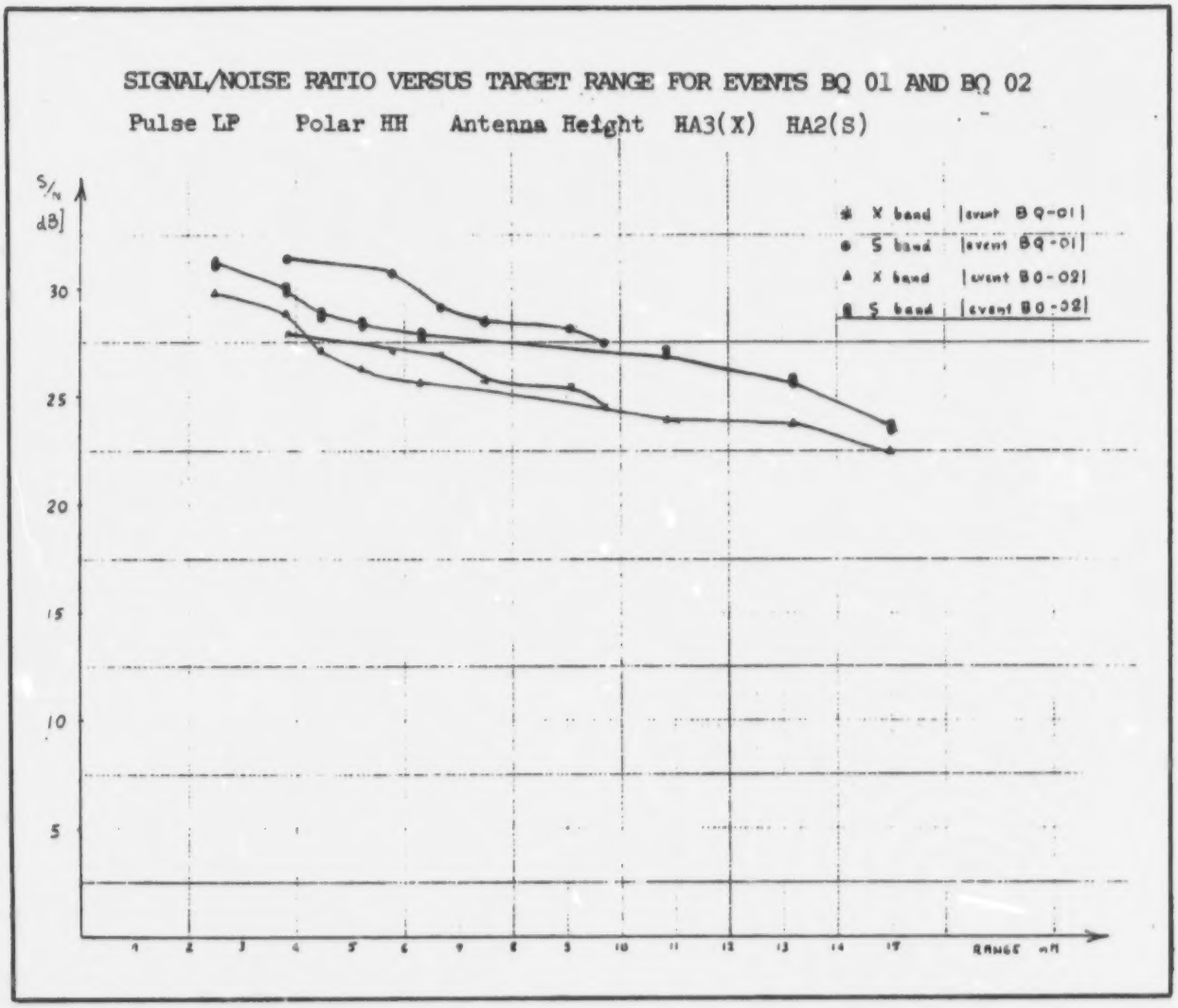

SIGNAL/NOISE RATIO VERSUS TARGET RANGE FOR EVENTS BQ 01 AND BQ 02
Pulse LP Polar HH Antenna Height HA3(X) HA2(S)
S/N dB]
30
25
20
15
10
5
X band (event BQ-01)
S band (event BQ-01)
X band (event BQ-02)
S band (event BQ-02)
RANGE nm

FIGURE 5.15

5.4.4 Detection of Icebergs in Various Sea States

An analysis of signal to clutter ratio versus sea state is limited by a shortage of events in higher sea states, that is higher than sea state 3 (see table 5.6).

Looking at the notes in the log book is was presumed that a few different ship's crew members were taking notes and make subjective estimations. During one event over a period of 1/2 hrs., the sea state changed from 4 to 6 and back to 4 again.

Sea State	Events Considered
0	CH-04, AO-03
1	AB-10, AA-03, AG-06, AG-07, AH-09, AO-02, CO-03, AG-08
2	AE-14, AJ-04, AK-09, AS-01, BM-01, BX-02
3	AW-03
4	BQ-01, BO-02
5	BQ-01
6	BO-02

Table 5.6
SEA STATE FOR THE VARIOUS EVENTS

Targets were grouped in two ranges: 3-3.6 nM and 8-10 nM and counted and a mean calculated in order to eliminate an additional parameter. Subsequently, attempts were made to find the proper formations of data points and perform the calculations on Fig. 5.16 with four lines suitable to radar band and range. Randomness of the data basically eliminated any chance of correlation because it is too difficult to organize the data if there are too few points. Proper conclusions from a statistical point of view are not possible . Remotec measured only sea clutter with no calibrated targets. To measure small targets in high sea state and long range is very difficult. The result may be variable and nonrepeatable each time the target is measured. This is caused by the bearing cursor not being lined up in the same relative position on the iceberg for subsequent scans.

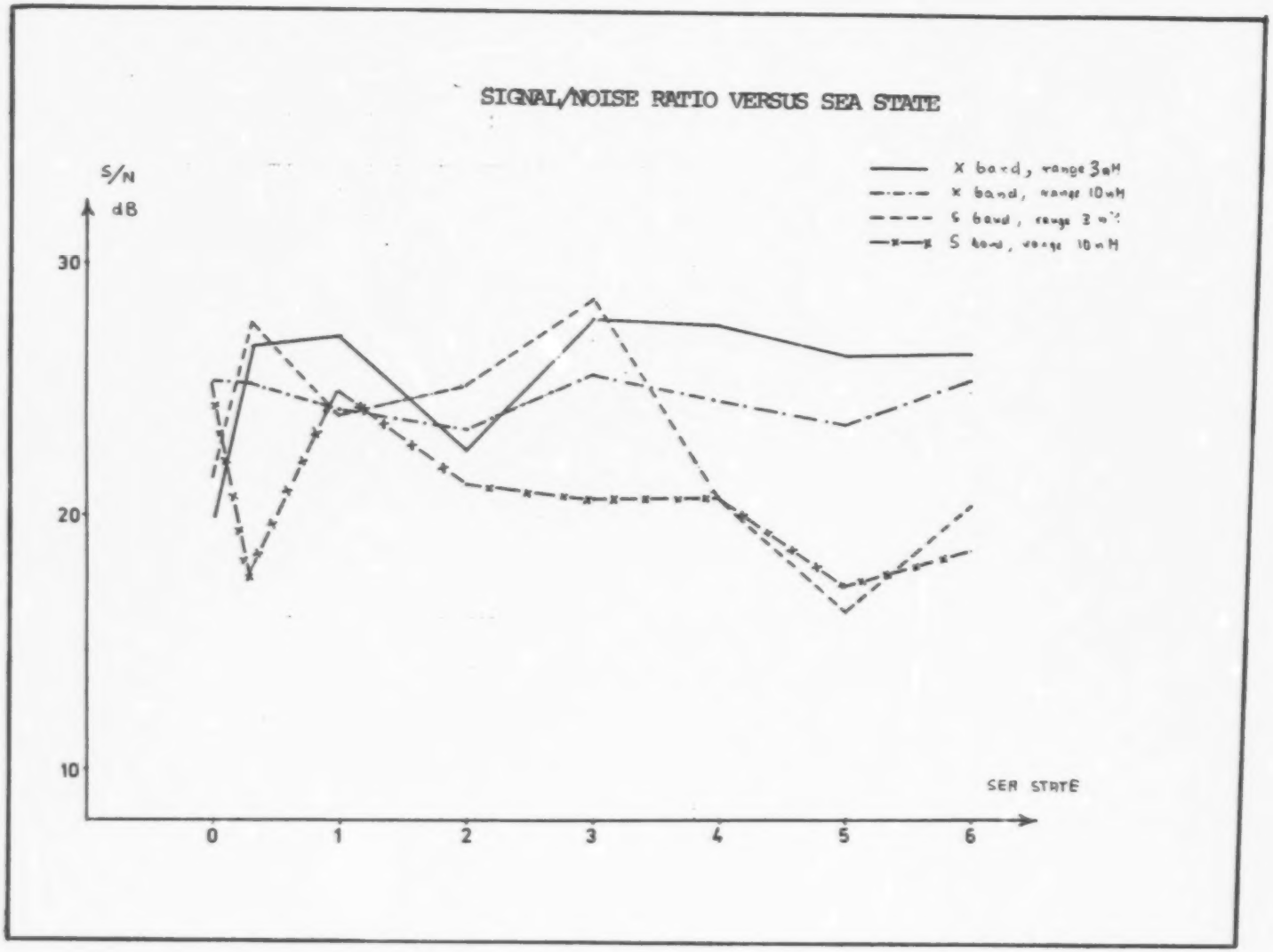
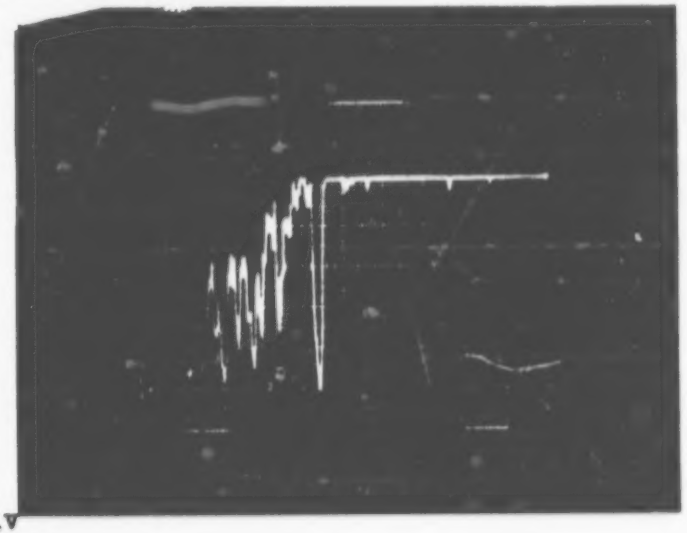

SIGNAL/NOISE RATIO VERSUS SEA STATE
S/N
dB
30
20
10
X band, range 3nM
X band, range 10nM
S band, range 3nM
S band, range 10nM
SEA STATE
0
1
2
3
4
5
6

FIGURE 5.16

In sea state 6, it was observed that sea clutter produced signals of almost the same amplitude as the target observed. This effect is shown on the pictures below in Fig. 5.17

event B0-02
X-band
Seq-13
combin 6
bearing 030
counter 849
tape 170
range 3.31 nM
horiz. 10 μs/div
vert. 0.5 V/div.



event B0-02
S-band
seq-13
combin 6
bearing 030
counter 849
tape 170
range 3.31 nM
horiz. 10 μs/div.
vert. 0.5 V/div.

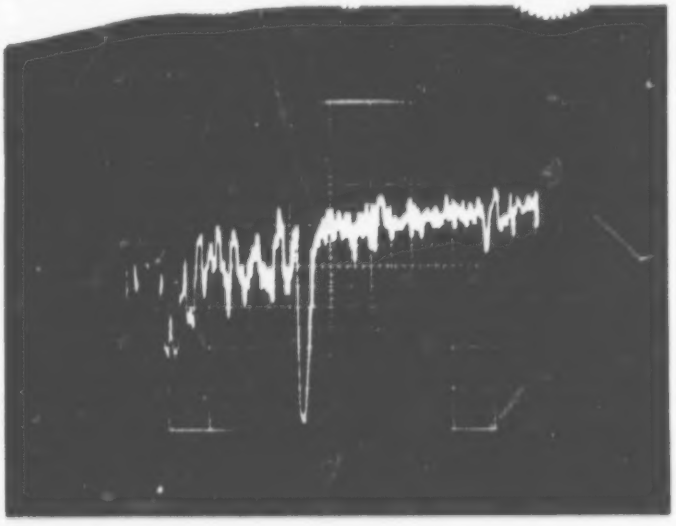


Figure 5.17
Signal Returns During Sea State 6

5.4.5 Signal/Noise Ratio Versus Target Size

In order to make this comparison, a series of events were grouped in categories of targets in ranges between 1 to 5 nM in order to avoid signal attenuation for longer ranges. To measure signals reflected from targets situated closer than 1 nM is not possible because the antenna propagation factors. Antenna propagation patterns were taken by Remotec staff by using reference targets. (Appendix A of the Petro Canada report). In our opinion this pattern, is doubtful, because it is hard to exclude the environmental factors for the calculated results, but referring to that graph and our observations, taking radar ranges below 1 nM is useless for any quantitative evaluations, especially for small target observations.

Because of poor target documentation it was necessary to use the variable range marker on the B & W scanner to attempt an approximation of target size. The width of targets was determined as a difference between distance of the near side of the target (VRM circle line just touching the near side of target) and the far side of target.

$$R_2-R_1 = Wx1852 = W \text{ (meters)}$$

Length of targets are determined by reading (from A-scope bearing switch) the appropriate bearing on both edges of the target as an angle inclusion between two hypoteneuses of congruent triangles. See Fig 5.18

The accuracy of this determination depended upon the selection of points A and B and judgement using the range meter in the B & W calibration. The VRM line was not as sharply defined on longer distances and smaller targets and therefore decreased the accuracy of the measurements

The inadequacies of this measurement technique are understood, especially for fast moving targets displayed on low resolution screens with low phosphor decay. With the poor gound truthing available this method was used as a last result.

5.4.5.1 Signal/Noise Ratio Versus Target Size Calculation

Method: targets were selected with a range of 1-5 nM using the classification system described in Table 5.9.

All targets size calculations were compared with logged data comments in the master logs and supporting documentation.

Determining target size from the radar display was accomplished as follows:

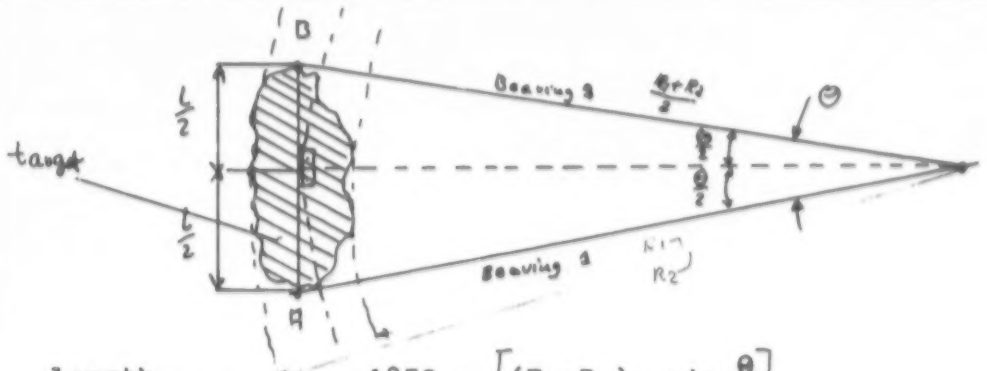


Fig. 5.18
TARGET SIZE DETERMINATION

1. On radar display the following measurements were taken:

   VRM circle before target - R_1 readout directly from counter on B & W display (nM)

   VRM circle after target - R_2 readout directly from counter on B & W display (nM)

   Bearing 1 - readout from A-scope switch (in degrees)

   Bearing 2 - readout from A-scope switch (in degrees)

2. Determine Width: - $R_2 - R_1 = W \times 1852 = W$ (meters)

   - 1 nM = 1852 meters

3. Determine Length: - L (meters) = $[(R_1 + R_2) \sin \Theta/2] \times 1852$

The accuracy depends on selecting points A and B and range readout on the B & W radar display.

The VRM line is not sharp on longer distances and small targets and reduces accuracy as a result.

TABLE 5.7
Signal Noise Ratio Versus Target Size:

EVENT	LENGTH(M)	WIDTH(M)	AREA (M^2)	RANGE (NM)	S/N(dB)	U.S. COAST GUARD CLASSIFICATION
AA-03 X	275.4	314.8	86695	4.26	33.06	
S	360	414.5	143831.5	4.26	31.02	Very large
BM-01 X	149.9	166.7	24988	1.16	29.98	
S	179.6	222.4	39943	1.16	23.96	Large
AB-10 X	279.22	277.8	77567.3	1.38	26.62	
S	291.87	259.28	75676.05	1.38	27.04	Very Large
CO-03 X	416	296.3	123260.8	1.64	28.94	
S	542.9	27.78	150817.6	1.64	32.04	Very Large
AW-03 X	240.63	333.36	80216.4	2.13	33.25	
S	275.2	351.8	96815.4	2.13	35.84	Very Large
AD-10 X	247.8	333	82517.4	3.115	28.94	
S	299	277.8	83062.2	3.115	30.18	Very Large
AD-10 X	194	203	29282	3.25	24.33	
S	209.8	203.8	42757	3.25	26.17	Large
CH-04 X	549	74.08	4066.9	4.21	20.82	
S	683	92.6	6324.6	4.21	22.92	Small
CH-04 X	36.48	18.52	675.6	1.41	21.9	
S	46 m	18.52	851.9	1.41	23.22	Small
BQ-01 X	100	37.04	3704	3.87	23.6	
S	105	40.5	5062.5	3.87	24.43	Medium
BX-02 X	110.4	55.56	6133.8	4.88	23.0	
S	116.7	74.08	9385.9	4.88	23.8	Medium
AH-09 X	180.15	93	18050	2.59	28.52	
S	200	105	21000	2.59	30.00	Large

TABLE 5.8
AVERAGE SIGNAL/NOISE RATIO VERSUS TARGET SIZE
FOR A RANGE OF TARGETS FROM 1.38 TO 4.88 km

X BAND	$\bar{x}$ mean							
Very Large	33.06	Large	28.52	Medium	23.6	Small	20.82
	26.62		22.98		23.0		21.90
	28.94		29.98	$\bar{x}$	23.3 dB		20.40
	23.25		24.33			$\bar{x}$	21.04 dB
	28.94	$\bar{x}$	26.45 dB				
$\bar{x}$	30.16 dB						

S BAND							
Very Large	34.32	Large	30.00	Mediu	24.43	Small	22.00
	27.04		23.96		23.80		22.92
	32.04		26.17	$\bar{x}$	24.115 dB		23.22
	35.84	$\bar{x}$	26.71 dB			$\bar{x}$	23.71 dB
	30.18						
$\bar{x}$	31.88 dB						

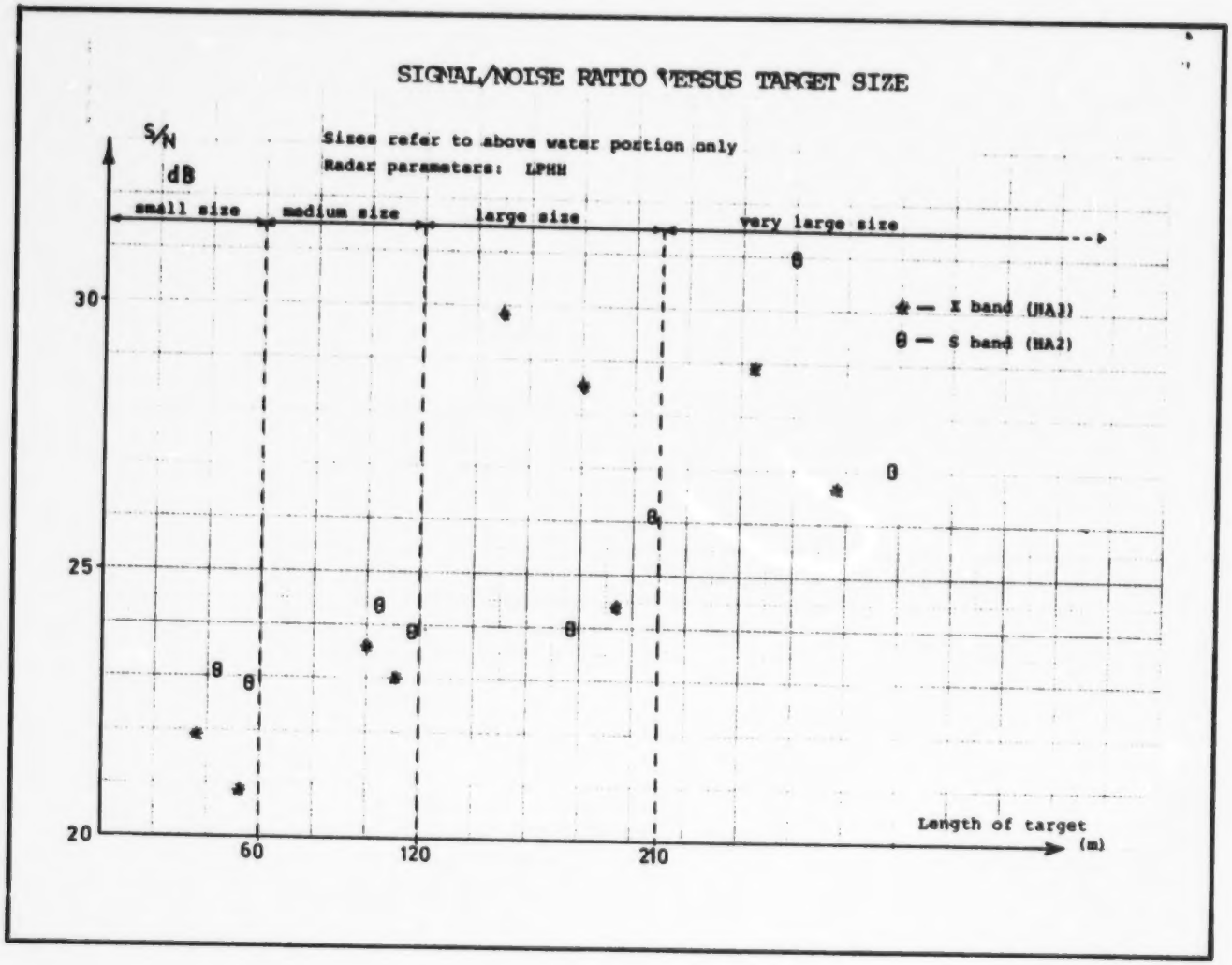

SIGNAL/NOISE RATIO VERSUS TARGET SIZE
S/N
dB
Sizes refer to above water portion only
Radar parameters: LPHH
small size
medium size
large size
very large size
* — X band (HA1)
θ — S band (HA2)
30
25
20
60
120
210
Length of target
(m)

FIGURE 5.19

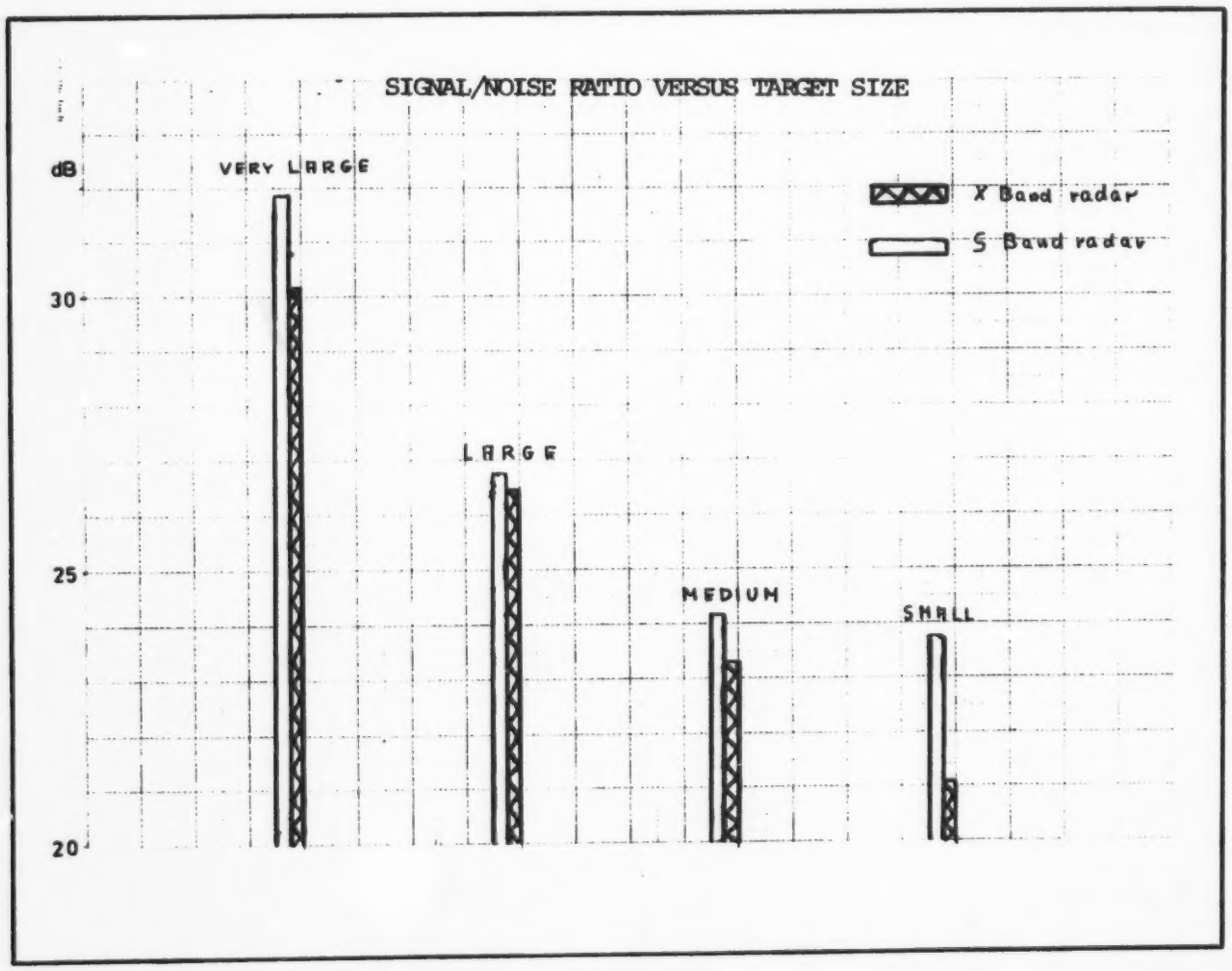

SIGNAL/NOISE RATIO VERSUS TARGET SIZE
dB
30
25
20
VERY LARGE
LARGE
MEDIUM
SMALL
X Band radar
S Band radar

FIGURE 5.20

Organization of the targets was taken by using the classification system based on USCG nomenclature; the same as in table 5.2 on page 88 of the Petro Canada report.

Icebergs	very large -	length greater than 210m
(except tabular)	large -	length 120 - 210m
	medium -	length 60 - 120m
	small -	length less than 60m

Table 5.9 Iceberg Size Classification

All initial selections are based comments from the Remotec Field logs.

The following events were used and classed as follows:

a/ Very large targets on events AA-03, CO-03, AB-10, AW-03, AD-10

b/ Large targets on events BM-01, AD-10

c/ Medium targets on events BQ-01, BX-02

d/ Small targets on events CH-04

Results of the measurements of the signal/noise ratio for the different sizes of targets is shown in Table 5.8

5.4.5.2 Conclusion:

Referring to Fig. 5.19 it is possible to conclude that the larger targets produce on the output of the radar receiver signals of greater magnitude in both steady and fixed radar parameters. In addition, Fig. 5.20 shows that the S band radar has a larger S/N return for comparable targets, although due to the inacurracy of the measurements ($\pm$ 20%), only low confidence can be placed in the results.

5.4.5.3 Discussion:

The qualitative point of view about target classification is described in Petro Canada report on Page 91. When making comparisons of the methods for determination target size by photogrammetry and volume by multiplying planimetric area by mean height, it is recommended to use the latter method, as it seems to be most accurate in our opinion. It does require additional photo-measurements to be made which were not done for most parts of the data collected. For the above water part of targets detection by radar system height of antenna placement and polarization should be correlated in target sizes but if targets are classified by length and width only and not supported by data about the shape (and height) - total error can occur as much as 50% (height estimation by photogrametric method generates up to 28% error). The same basic conclusions and recommendations are described in page 91 of the Petro Canada report.

5.5 Conclusions

In the Introduction, the objectives of the data assessment and evaluation were pointed out. The data was viewed in several contexts which enabled one to derive different types of information from the data. Once the data was sorted and categorized with the most useful targets selected, certain analyses were conducted to try to make useful conclusions from the raw data. Subsequently the use of the data as an input to other individual experiments was explored and finally, lessons learned from this initial data acquisition could be inferred. This would naturally lead to recommendations for future cruise activities that would eliminate some of the problems encountered during the first field experiment and ensure a better data set was collected during future field activities.

As a direct result of experiment, some basic general conclusions can be made which support previous theoretical claims of radar performance against ice and iceberg targets. These conclusions are admittedly very general, but are a reflection of the quality of the recorded data. In addition, these conclusions can be used to support or refute the conclusions drawn by Remotec in their analysis.

Generally, the S-band radar produces a stronger output signal to noise ratios than the X-band radar. This is true for all combinations of antennas and pulse widths within the limitations of the inherent errors of the sytem. The X-band radar suffers from less signal attenuation with distance than the S band radar in steady weather if no precipitation is present. The best combination of operating parameters is to utilize a long transmitting pulse, horizontal polarization. Within the freedom of choice allowed for in the experiment, 12.5 m antenna height for the X-band radar and 15 m antenna height for the S-band radar is optimal. In general signal returns from both types of radar are more dependent upon pulse width than upon the antenna height.

With the optimum choice of radar operating parameters determined, several comparisons were made and an attempt to draw conclusions were made. One comparison was concerned with signal to noise ratio versus the target range. Generally, the sea clutter level was responsible for the signal/noise ratio and signal/(noise and clutter) ratio. For steady seas, the sea level clutter collection effect is direct proportional to the range. However, it was not possible to objectively perform a correlation between sea state and clutter levels. In addition, it was not possible to make a sea state comparison with the signal to noise ratios. Here again, there were too many degrees of freedom and for measurement of small targets in high sea states at long ranges, it was impossible to obtain repeatable measurements of signal to noise ratios due to instability of the platform when the radar was triggered, causing reflections from different areas of the target.

Calculation of signal to noise ratio versus target size was also attempted. It is reasonably safe to conclude that larger targets produce larger signal to noise ratios. This seems obvious, however, and for future signal enhancement experimentation using these targets as a data input, this may be a useful conclusion.

The generally inconclusive results of this analysis point out the poor methodology used. This casts a great deal of suspicion over the whole set of data. From the beginning, the radar system was not calibrated on board the ship, and so no idea of how the system affects the signals has been gained. System parameters and losses were calculated in the laboratory or factory based upon theoretical considerations. No understanding was gained about the movement of the antennas beam pattern on an unstable platform, especially considering the variation vertically which would reduce the power impinging upon the target. There is little evidence of system losses or transmitted power than can be determined from the Remotec report, hence the ability to determine signal to noise ratios is limited.

Remotec concentrated upon too many targets and did not collected enough data upon each. Instead, fewer targets ranging through all desired sizes of ice, well documented with a great deal of video data for each would be much preferred. Instability of the platform and recording of video after clutter suppression as opposed to recording raw video would be preferable.

These conclusions summarize the attempts to derive useful information from the raw data itself without further processing. Although these conclusions are subject to low degrees of confidence, they are useful from the point of view of comparison with the Remotec conclusions to validate their efforts. This was not the principal reason for evaluating the data however, and this should be kept in mind.

The major reason for the evaluation was to determine whether or not the data was worth digitizing for use in experiments concerned with digital signal enhancement. The target selection process eliminated most of the data from being used for this purpose, however, some of the data may be very useful indeed. The limitations described above are not overly restrictive in the case of evaluating signal processing methods upon the data. This case requires a record of raw video and good ground truthing in the form of locating the targets and having pictures taken of them for identification puposes. Eighteen targets have good ground truthing. Good ground truthing was documented for the large icebergs. The returns from smaller ice bits have little correlated ground truthing. This presents the problem of once having developed an enhancement algorithm, it would be difficult to actually verify that the enhanced signal was in fact an iceberg or bergy bit. At most, 5 scans were made of each iceberg thus giving no base to form a statistical description of the returns. This is important in processing techniques. These problems, while serious, are not insurmountable. For this reason it is recommended that further efforts be made to attempt digitization and scan conversion and then use a variety of techniques to try and improve signal to noise ratios.

The last major objective of the program was to draw conclusions from the data that would enable recommendations to be made for future field programs that would significantly improve the methodology for measuring iceberg parameters and sensor parameters. This may be the most important use for the data, and with the equipment installed aboard the trial vessel as a prototype ice hazard detection system for evaluation purposes only, the experiment may be described as very successful. The shortfalls of the data collection activity point out areas that need to be addressed in future trials. To conduct experimentation in the future, a program will need to be more thorough, equipment requirements and configuration must be changed, and measurement techniques improved. Future program plans should incorporate the following changes:

a) Data collection should occur only if significant targets are presented. It is unnecessary to collect and continuously record data if there are no targets visible.

b) The field data collection should be done only with a few of the desired targets with indisputable ground truthing to accompany it. This would include providing information regarding target bearing and range on the voice edge of the video-taped recording to improve data assessment. In addition, better correlation needs to be made between photo and video recordings of the targets. It should be ensured that if there are multiple targets in a picture, that each one is individually correlated with range and bearing on the video recording.

c) The number of radar scans for each target sequence should be increased to at least 10 to ensure restrictions on subsequent signal processing are not imposed.

d) Radar system calibrations should be conducted in the field in actual or simulated modes of operations.

In the area of equipment improvements present off the shelf marine radar is not effective as a data collection set. The following improvements are necessary:

a) Research quality radar should be designed and should include all polarization capabilities in both transmit and receive.

b) The received signals should be recorded as early in the receiver stage as is possible. These signals should be raw video. The characteristic of the receiver should be linear in certain ranges, rather than logarithmic. Although logarithmic characteristics are required for operational marine detection and navigation which provides an automatic gain compensation for display purposes without concern for the amplitude of the received signals, this is not ideal for experimental and research programs. In order to obtain the best parameter evaluation it is necessary to linearize all systems as best as is possible.

c) Recording should occur on high quality recording systems, whether analog or digital. Noise generated by parts of the recording system should be known and documented.

d) Experiments should be conducted at all polarizations in order to determine optimum antenna design and to maximize the signal to clutter ratio.

e) The radars should be stabilized and installed on a large ship or stable platform so ships movement is not transferred to the detection system. This will enable verification and reproducibility of data.

f) To locate small or weak returns from the clutter, computer processing will have to be accomplished. This, however, should be done seperately from the field experiment. In the field all that is required is to detect all returns and record them. Future processor based radar or displays can then be designed around the results of these research activities. If ground truthing is well documented, processed signals detected from within the clutter will be easily verifiable.

Measurement techniques that should be improved are described here:

a) Receivers should be initially calibrated by using laboratory microwave generation noting sensitivity and reference levels and recording this on the video tape.

b) Both systems, if two are used, should be switched on and recording conducted simultaneously from maximum observation range (usually about 12nM) to minimum observation range at the same time as range, bearing, time, speed information and sea state are added to the voice edge. Improved methods should be used to determine sea state such as wave rider bouys.

During the inbound run, every 1nM or so, orientation comments should be added and noise levels and signal strength measured by meter. Equivalent energy output on both systems should be achieved.

c) Photographs and notes should be taken simultaneously and the size of target should be accurately determined by photo-measurement equipment or preferably, physical measurement if possible. Use of a radar calibration bouy would be ideal.

d) A steady antenna speed is probably preferable to reduce the number of switching modes. In the opinion of the REMOTEC staff, higher antenna rotation speeds produce more reflected energy in the luminopher tube producing good contrast visibility on the display.

e) As stated earlier, make a minimum of 10 scans for each combination of radar parameters.

f) For better ergonomical facility, it should be possible to design an electronically linked bearing adjustment on the B & W linked bearing scanner and the A-scope trigger if such a configuration is utilized in future. At present, it is very difficult to follow the target after adjusting two separate tuning controls. This will facilitate preparations for continuous digitization and conversion of signals.

If these recommendations are implemented, a data base will be built up that will be extremely valuable due to its completeness, high degree of confidence in the measurements and its utility for a wide variety of signal enhancement, radar design and modeling programs.

6.0 Analysis Plan

Although the data evaluated has certain pitfalls, it is reasonable to expect that a few of the well documented targets will permit signal enhancement techniques to be attempted with a reasonable assurance of success. Although this is not guaranteed, it is the only known available data set in existence. The display processing being undertaken at McGill currently has no access to real iceberg target data and this data would provide an opportunity for research. The Communications Research Laboratory of McMaster University has also expressed interest in the data and may be able to utilize it to test some of their algorithms. With this in mind the following activities are recommended.

An extensive analysis of the iceberg targets selected during this study should be undertaken to trial various signal processing algorithms. Using a dynamic threshold processor, experimentation can be undertaken to enable signal returns to be improved through the electronic removal of spurious noise. Subsequently this pre-processed analog data set, as well as the unprocessed data, should be digitized in a format suitable to the end user of the data.

Scan conversion should then be attempted to convert the polar formatted data into cartesian formatted data. Once this has been completed, the data may be redisplayed in a digital television format. This will enable a variety of signal processing techniques to be applied. These techniques can range from standard scan to scan averaging techniques to more sophisticated comparative decorrelation spectral analysis and trials using amplitude distribution discriminators. These techniques should be discussed with those concerned with the use of radars for offshore and maritime iceberg detection to solicit their suggestions and opinions.

7.0 Conclusion and Recommendations

In section 6.0, the recommendations deal with the immediate suggestions for use of the radar data. In the longer term, the results of any processing could be used in conjunction with a longer range modeling program.

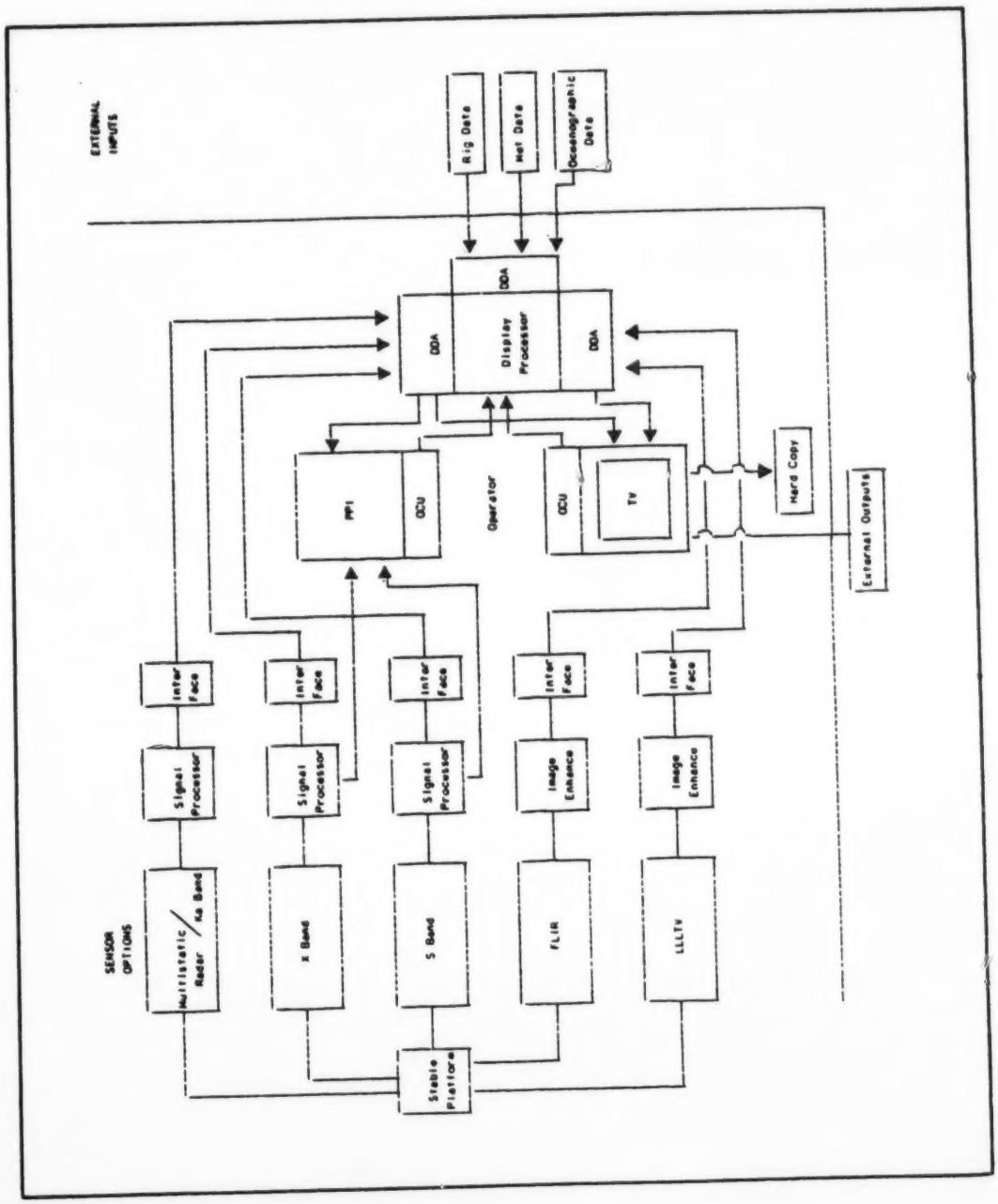
The overall objectives of the development of improved ice hazard detection systems is to improve the probability of detection of ice and icebergs by various sensors. For radars this can be accomplished by making calculations which express the probability as a function of the ratio of target signal to system noise level or target signal to background clutter. These calculations have been made for certain situations in the offhsore. In particular, the Newfoundland Petroleum Directorate, as mentioned in Chapter 2, has conducted such a study. These calculations should be expanded to cover all situations within the Canada waters for all commercially available radars and radars under development. A model could be developed to produce these probabilities of detection. Such a model could then be used to quantitatively evaluate the various processing improvements which are described here. This would be a valuable study to ensure the proper sensors are selected for any proposed ice hazard detection system. Such a model would produce an overall figure of merit for each radar based on detection range for a specified target. This model could also be used to evaluate the aplicability of the various signal enhancement techniques available and under development for use in different environments and incorported in different sensors. Data such as that which has been evaluated during this study could be used to support these findings.

In the long term, this evaluation has pointed out the need for an improved data base. Detection of ice at sea is a new field of research, and therefore it is difficult to pinpoint a priori the form of the data that should be collected. Perhaps the most significant finding of the evaluation has been the realization that the Remotec data does not inspire a high degree of confidence due to the measurement techniques utilized. This points out the need for another field data gathering exercise which can capitalize upon the pitfalls of the Remotec experiment. Such an experiment could provide high confidence data that could be used to support many experiments and studies now underway and planned. It would be ideal for any model development and it could be used to verify the results of immediate processing exercises which are contemplated using the currently available data.

The suggestions thus far have concentrated on radar data collection, evaluation and processing. Futher efforts should be undertaken to continue with the development of the IHD/CAS system specification.[8] This system will be the targeted end user of the sensors identified through whatever means as the most effective ice and iceberg detectors, and as a result, should be capable of accommodating them.

Finally, the Transportation Development Centre should continue its efforts to coordinate, plan and fund activities which encourage and support the development of any ice and iceberg detection system.

ANNEX A



IHD/CAS BLOCK DIAGRAM

LIST OF ABBREVIATIONS

PD	=	Probability of detection
Pfa	=	Probability of false alarm
IHD/CAS	=	Ice Hazard Detection/Collision Avoidance System
CFAR	=	Constant false alarm rate
FTC	=	Fast time constant
STC	=	Sensitivity time control
S/N	=	Signal to Noise ratio
HH	=	Horizontal polarization
CP	=	Circular polarization
LP	=	Long pulse
MP	=	Medium pulse
HA	=	Height of antenna
VRM	=	Variable range marker
nM	=	Nautical miles

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